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The impact of growth, volatility and competitive advantage on the value of equity investments and their embedded options

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Jason Hall

University of Queensland Business School

Statement of originality

To the best of my knowledge and belief, the material submitted in this thesis is my own, except where otherwise acknowledged. This work has not been submitted, either as a whole or in part, for a degree at this or any other university.

Jason Hall

Date 15/2/06

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Abstract

This thesis examines the relationship between equity valuation and four value drivers – revenue growth, volatility, profit margin and competitive advantage. It is motivated by evidence that the predominant valuation techniques of equity analysts are not associated with improved portfolio performance. Prior research suggests that equity analysts devote considerable resources into forecasting near-term earnings, but derive target prices from those earnings in an almost arbitrary fashion. In contrast, the valuation techniques in the commercial world are increasing in sophistication. Around 30 percent of large corporations in the United States and Australia use real options analysis for project evaluation, according to recent surveys. Thus, the research question is whether sophisticated equity valuation, based on rigorous economic assumptions, is useful for investment decision-making.

Chapter 2 examines whether equity portfolios formed using *Decision-tree* or *Discounted Cash Flow* valuation models earn positive abnormal returns. These valuation models incorporate the assumption that abnormal returns on reinvested earnings are eroded over time. I form long-short portfolios on the basis of value relative to price at 30 April of each year from 1987-2004, by selecting stocks ranked in the top and bottom deciles, top and bottom quintiles and the top 30 percent versus the bottom 30 percent. I report annual excess returns of around 7 percent and a significant improvement in Sharpe ratios. Despite a strong relationship between value/price, size and market-to-book equity, this outperformance remains after controlling for these factors. Further, abnormal returns were most consistently earned by portfolios formed from a sub-sample of small growth stocks. The results are consistent with the following explanation for the outperformance of value stocks – investors extrapolate past earnings and revenue growth for an unreasonably long competitive advantage period. The implication for portfolio managers is that there is merit to fundamental valuation techniques, provided they incorporate the assumption that firms' competitive advantage is unlikely to be sustained into perpetuity.

Chapter 3 measures the relationship between IPO underpricing and the proportion of equity value attributable to the firm's embedded options, referred to as *Real option%*. In estimating this proportion, I compute *Discounted Cash Flow* and *Decision-tree* valuations under the assumption that revenue growth, volatility of growth and profit margin revert to long-term sustainable levels over the firm's competitive advantage period. Consistent with information asymmetry theories of underpricing, there is a significantly positive association between initial returns and *Real option%*. The results are consistent with the value of embedded options being priced at a 10 percent discount to market value, in addition to any strategic underpricing. In contrast, the evidence suggests that information asymmetry does not prevent the *Discounted Cash Flow* component of equity value being fully incorporated into offer price.

Chapter 4 provides corroborating evidence that *Real option%* is a measure of the proportion of equity value comprised of embedded options. First, I show that *Real option%* is positively correlated with *R&D*-intensity and that around 30 percent of the variation in *Real option%* can be explained by *R&D*-intensity. Second, I show that *Real option%* and *R&D*-intensity have comparable association with the volatility of stock returns. Third, I estimate the market value of embedded options on a per share basis. When the market value of embedded options is estimated using capitalised *R&D*, the confidence interval around this value is comparable to that implied by *Real option%* under an assumed competitive advantage period of 20 or 30 years. When this confidence interval is estimated using *R&D*/Sales, it is comparable to that implied by *Real option%* under an assumed competitive advantage period of 10 years. Finally, I show that quintile portfolios formed on the basis of *Real option%* have comparable investment performance to those formed on the basis of *R&D*-intensity. Sharpe ratios for the top and bottom quintiles formed on *Real option%* were 0.40 and 0.41, respectively. Furthermore, Sharpe ratios of 0.34 and 0.38 were obtained for those same quintiles for portfolios formed on the basis of *R&D*/Sales. In sum, this analysis provides support for *Real option%* as a valid economic construct – the proportion of equity value comprised of embedded options.

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Chapter 1

Introduction

This thesis consists of three papers which examine the relationship between equity valuation and four value drivers – revenue growth, volatility, profit margin and competitive advantage. I derive equity valuation models which are more robust than those used by equity analysts in practice, but whose parameters can be estimated with little more data than already generated by those analysts. The thesis is motivated by evidence that the predominant valuation techniques of equity analysts are not associated with improved portfolio performance. Prior research suggests that equity analysts devote considerable resources to forecasting near-term earnings, but derive target prices from those earnings in an almost arbitrary fashion. In contrast, the valuation practices of industrial firms show an increasing level of sophistication. Around 30 percent of large corporations in the United States and Australia use real options analysis for project evaluation, according to recent surveys. Thus, the research question is whether equity valuation, based on rigorous economic assumptions, is useful for investment decision-making.

I evaluate this research question in three settings. First, I examine the performance of stock portfolios formed on the basis of two equity valuation techniques – *Discounted Cash Flow* and *Decision-tree* valuations. The predominant underlying assumption is that firms' competitive advantage is unlikely to be sustained indefinitely. This implies that long-run expected returns on reinvested earnings are equal to the cost of capital. In the *Discounted Cash Flow* model, I implement this assumption by ensuring that revenue growth and profit margins revert to long-term expected values over an assumed competitive advantage period *(CAP)*. In the *Decision-tree* model, I incorporate an estimate of the value of management's option to alter reinvestment policy, in response to signals regarding expected future growth. I implement this assumption by simulating earnings over the competitive advantage period and computing the mean valuation which results from those simulations.

Second, I examine whether the proportion of equity value consisting of embedded options (*Real option%*) can explain the underpricing of initial public offers (IPOs). If there is greater uncertainty over the value of embedded options, relative to the value of expected cash flows, information asymmetry theories predict a positive association between *Real option%* and IPO underpricing.

Third, I examine the validity of *Real option%* as an economic construct, by measuring its association with research and development (*R&D*) expenditure. I then examine the association between *Real option%*, *R&D* expenditure and stock prices, returns and volatility. The three studies are summarised below.

1. Valuation of high-growth equities

This study examines the relative ability of a *Decision-tree* valuation model and a *Discounted Cash Flow* valuation model to identify stocks which subsequently earn abnormal returns. Both models rely on the assumption that revenue growth and profit margins are expected to revert to long-term values which are consistent with normal return on investment over an assumed competitive advantage period. The *Decision-tree* model allows investors to value the firms' growth and abandonment options, created by management's ability to respond to high- and low-growth environments by altering investment policy. In addition, the models are equally applicable to profitable and loss-making firms, given that they include separate estimates of revenue growth and profit margin. This contrasts with textbook valuation models which typically rely on an estimate of earnings growth.

The modelling techniques allow investors to quantify the proportion of equity value not captured by the present value of expected future cash flows. This is especially important for stocks characterised by high growth, a high level of innovation and significant probability of failure. Firms with these characteristics are likely to have above-average values of their abandonment option. Further, their higher volatility of revenue growth means that their growth options have above-average value. This occurs because investment policy is expected to change in response to feedback regarding the firm's growth prospects. This argument finds support in the corporate finance literature on the diversification discount. While there is conflicting evidence as to whether the average diversified firm trades at a discount, there is agreement that losses in value occur because of relative over-investment in low growth segments, compared to high-growth segments (Villalonga, 2004; Berger and Ofek, 1995).

This study is motivated by the emerging use of real options valuation in corporate finance practice (Graham and Harvey, 2001; Truong, Partington and Peat, 2005) and its contrasting minimal use by equity analysts who largely rely on multiples-based valuation (Asquith, Mikhail and Au, 2005; Demirakos, Strong and Walker, 2004; Block, 1999; and Bradshaw, 2002). The overwhelming use of earnings multiples by analysts to justify recommendations or target prices can be justified if they lead to subsequent outperformance. However, there is no evidence that this is the case (Bradshaw, 2004; Asquith et al).

Furthermore, there is growing theoretical and empirical evidence that market prices exceed *Discounted Cash Flow* valuations and this difference can be attributed to option value (Berger, Ofek and Swary, 1996; Schwartz and Moon, 2000 and 2001; Bernardo and Chowdry, 2002; Quigg, 1993). A preliminary examination of the theoretical and empirical valuations of my sample support this contention. Median *Discounted Cash Flow*/price ratios are considerably less than one (0.49 – 0.54) but are comparable to those computed by Bradshaw (2004). In contrast median *Decision-tree* values are in the range 0.70-1.04 for 10 of 11 industry sectors, when the assumed competitive advantage period is 30 years.

Application of the models resulted in significantly positive excess returns. I formed long-short portfolios by selecting stocks ranked according to value relative to price on 30 April each year from 1987-2004. For the full sample, long-short portfolios formed from the top and bottom deciles of this ranking earned excess returns of around 7 percent a year. However, performance was largely insensitive to the valuation method used or the assumed competitive advantage period (10, 20 or 30 years). This occurred because 60 percent of stocks were ranked in the same decile for all six valuations performed. Outperformance was most consistent for long-short portfolios formed from a sub-sample of small, high market-to-book stocks, and there is no evidence of outperformance amongst long-short portfolios formed from large, high market-to-book. This is consistent with the explanation of Lakonishok, Shleifer and Vishny (1994) for the value-glamour anomaly, that investors extrapolate past earnings growth for an unreasonably long competitive advantage period. The models used in my study prevent this from occurring, but achieve their most consistent performance amongst a sub-sample in which this extrapolative bias is most likely to be present.

Excess returns remained even after controlling for three definitions of risk – portfolio volatility, Fama-French factors and default risk. Portfolios of stocks with high value/price ratios had significantly higher Sharpe ratios than portfolios with lower value/price ratios; and long-short portfolios had significantly positive intercept terms in four-factor regressions. Default risk is a concern, given that the valuation models typically identified small, low market-to-book stocks as undervalued and there is a strong association between size and credit ratings. However, the magnitude of the excess returns earned by long-short portfolios is significantly higher than the default risk premium required by debtholders.

An additional contribution of this study is that it enhances our understanding of sharemarket activity from 1998-2001, which was characterised by unusually high earnings multiples, a substantial increase in equity raisings and later claims that analyst research was tainted by the need to maintain corporate and investment banking relationships. The fall-out from this period included an $875 million settlement by ten broking houses with the Securities and Exchange Commission (SEC), the New York Stock Exchange (NYSE) and the National Association of Securities Dealers (NASD). But while there is substantial evidence that analyst research lacked objectivity for particular market segments, it is questionable whether this can be blamed for inflated equity prices in what is typically referred to as the 'tech bubble'.

For the sample analysed in my study, analysts' expectations for revenue growth or profit margins were not unusually high during this period, even for the Technology sector, nor was there unusual dispersion of those expectations. In contrast, the dispersion of fundamental value/price ratios increased significantly during this period. The result was that long-short portfolios formed as a result of those fundamental values typically earned negative returns during 1998-1999, the boom years for growth stocks. However, these losses were more than recovered during the subsequent two years. This evidence is inconsistent with the argument that analyst hype was a major contributor to inflated equity prices. But it is consistent with the argument that the sudden rise in equity prices was due to short sale restrictions (Ofek and Richardson, 2003), which would allow market prices to divert sufficiently from fundamentals for actively-managed funds to prosper.

2. IPO underpricing and the value of embedded options

This study explains the underpricing of IPOs as a function of the proportion of equity value consisting of embedded options, which I label *Real option%*. Investors in firms whose value consists largely of real options face above-average information asymmetry, which is expected to result in lower offer prices and higher returns on the first day of trade in the secondary market. This underpricing is in addition to any returns which result from underwriter or issuer incentives, which I term 'strategic underpricing.'

Recent evidence suggests that IPO underpricing is a strategic decision of underwriters and issuers (Ljungqvist and Wilhelm, 2002 and 2003; Aggarwal, Purnanandam and Wu, 2005; Houston, James and Karceski, 2004). However, there is also evidence that technology IPOs during recent years were consistently underpriced, even after controlling for strategic underpricing (Ljungqvist and Wilhelm; Loughran and Ritter, 2004). If there is above-average information asymmetry present in the float of a technology stock, we cannot entirely dismiss information asymmetry as a partial explanation for underpricing (Rock, 1986; Beneviste and Spindt, 1989; Koh and Walter, 1989; Beatty and Ritter 1986).

In this paper, I argue that an increase in the proportion of value comprised of real options increases the relative information advantage of sophisticated investors. They will be relatively better informed about the probability of technological success, given the information conveyed directly by management and indirectly by analysts, and will be better placed to value the stock, given this information set. Applying this argument to the informed/uninformed dichotomy, for stocks in which a higher proportion of value is comprised of real options there will be a larger percentage of uninformed investors. Then, according to the winner's curse model of Rock (1986), it follows that there should be a positive relationship between underpricing and the proportion of value comprised of real options.

I also argue that *Real option%* is positively associated with information asymmetry between issuers and investors. The value of embedded options results from the optimal exercise of growth and abandonment options by management, in response to new information. Even with increased disclosure to investors, an information gap is likely to remain, because of the proprietary nature of these options. Under this argument, the information asymmetry model of Beneviste and Spindt (1989) predicts a positive relationship between underpricing and *Real option%*.

A preliminary analysis of the data provides evidence that initial market prices of IPOs incorporate the value of embedded options. Their price-earnings ratios are positively associated with the cost of equity capital and the volatility of revenue growth. Furthermore, I show that the positive association between *Real option%* and volatility within the IPO sample can only be the result of volatility being priced by the equity market. In this study, the assumed competitive advantage period is selected to minimise the difference between *Decision-tree* valuations and market prices. I then estimate *DCF* values under the same estimated *CAP* and compute *Real option%*. If volatility is not positively valued by the equity market, this will result in under-estimating the *CAP* of high-volatility firms and over-estimating the *CAP* of low-volatility firms. *CAP* is positively associated with *Real option%*, so this would result in high-volatility firms having a low *Real option%* and low volatility firms having a high *Real option%*. This is not what we observe, which is a positive relationship between volatility and *Real option%*.

The results support the hypothesised relationship between underpricing and *Real option%*. The analysis suggests that, in the absence of any strategic underpricing, the value of embedded options are discounted by 10 percent. But the *Discounted Cash Flow* component is fully priced in the IPO. For an IPO with mean *Real option%* of 47 percent, this result predicts a 5 percent discount to market value. This discount is consistent with information asymmetry explanations for underpricing. However, strategic underpricing remains the dominant explanation for below-market offer prices as shown by the explanatory power of price revisions. Investment bankers leave money on the table by only partially adjusting offer prices from the mid-point of the filing range, despite their knowledge of investor demand gained during the book-building phase.

There are two implications of this paper. For investment bankers and issuers, it implies that IPO proceeds can be enhanced with efforts to ensure their clients are well-informed about the value of the firm's strategic options. This implication is consistent with the evidence of Schrand and Verrecchia (2004) who find that increased disclosure in the pre-IPO period is associated with lower underpricing. Issuers would also benefit from the use of simulation techniques for estimating the value of embedded options, the results of which can be used to ensure investors are fully-informed. Underwriters have an incentive to engage in this activity. The potential increased proceeds for the mean IPO are $11 million. This equates to increased underwriter fees of $1 million, assuming the typical underwriter fee of 7 percent.

For academics, *Real option%* quantifies information asymmetry in a way which has direct economic meaning. Proxies used in prior literature, such as share allocations to retail investors, the volatility of stock returns, or issue size, provide useful support for information asymmetry arguments. But their relationship with IPO underpricing is not necessarily linear, as assumed in the typical analysis performed. Nor is there any estimation technique to determine the point at which information asymmetry is reduced. For example, at what point do we consider a client to be a sophisticated investor? What is the threshold issue size at which information asymmetry is no longer material? In contrast, I show there is an approximate linear relationship between IPO underpricing and *Real option%*, and quantify this relationship using linear regression.

3. Research & development expenditure and the value of embedded options

In Chapters 2 and 3, I interpret the difference between the *Decision-tree* and *Discounted Cash Flow* valuations as the estimated value of embedded options. My contention is that this valuation is useful for decision-making by equity analysts, portfolio managers, investment bankers and equity issuers. I refer to the variable *Real option%* as the percentage of total equity value attributable to embedded options. The economic rationale for this interpretation is that volatility of the revenue stream gives rise to growth and abandonment options, which management can exercise by altering reinvestment policy.

In this study, I provide corroborating evidence to support this economic interpretation of *Real option%* . First, I show that *Real option%* is positively correlated with research and development (*R&D*) expenditure, which can be interpreted as the purchase of an option to proceed to commercialisation. There is a significant positive association between *Real option%* and *R&D*/Sales, *R&D*/Earnings and *R&D*/Dividends, and about 30 percent of the variation in *Real option%* can be explained by *R&D*/Sales. Furthermore, of the 41 industries represented, 6 were jointly ranked in the top 10 by both *R&D*/Sales and *Real option%* and 13 were jointly ranked in the top 20. The sample used in my study has comparable *R&D*-intensity to that analysed by Chan, Lakonishok and Sougiannis (2001).

Second, I show that *Real option%* is positively associated with the volatility of stock returns. I replicate the linear regression analysis of Chan et al (2001) who find a positive association between *R&D*/Sales and returns volatility. I find a comparable relationship between *Real option%* and returns volatility and report higher explanatory power. This result is consistent with the modelling of Schwartz and Moon (2000) who predict a positive association between the volatility of revenue growth and stock price volatility.

Third, I show that the market value of embedded options is comparable to the market value of investments in *R&D*. Lev and Sougiannis (1996) and Abrahams and Sidhu (1998) estimate a linear relationship between share price and capitalised *R&D*. I repeat this analysis after replacing the dependent variable with an estimate of the option component of equity value, expressed on a dollars per share basis. If *CAP* is assumed to be 10 years, market value of embedded options is comparable to the market value of annual *R&D* expenditure. If *CAP* is assumed to be 20 or 30 years, the market value of embedded options is comparable to the market value of capitalised *R&D*.

Finally, I examine whether there is a relationship between *Real option%* and the level of subsequent stock returns. Chan et al (2001) were able to find limited evidence of a positive association between *R&D*-intensity and stock returns. This evidence was confined to firms whose recent share market returns were poor, and therefore had high ratios of *R&D*/market value.

Whether we should expect *R&D*-intensive stocks (or stocks with high *Real option%*) to earn above-average returns is unclear. If the above-average volatility of *R&D*-intensive firms is due to a risk factor that is priced by the equity market, we should expect these stocks to earn higher average returns. However, *R&D*-intensive stocks can also be characterised as glamour stocks, given their relatively high market-to-book equity ratios and high earnings growth. Given that glamour stocks typically earn lower returns than value stocks, we could observe *R&D*-intensive stocks earning low average returns.

The results confirm that portfolios formed on the basis of *Real option%* have comparable performance to those formed on the basis of *R&D*-intensity. Stocks ranked in the top quintile by *R&D*-intensity had average annual returns of 12.9 percent, which was 2.6 percent higher than those in the bottom quintile. For stocks ranked according to *Real option%*, there was a comparable difference in performance of 2.4 percent. However, these differences in returns were not statistically significant. In addition, the higher volatility of returns in top quintile portfolios meant that their Sharpe ratios were slightly lower than those in the bottom quintile.

In conclusion, the association of stock prices, returns and volatility with *Real option%* and *R&D*-intensity is consistent with the interpretation of *Real option%* as a measure of option value.

Chapter 2

Valuation of high-growth equities

1 Introduction

This paper examines the relative ability of a *Decision-tree* valuation model and a *Discounted Cash Flow* model to identify mispriced equities. The models rely on the assumptions that revenue growth and profit margin are expected to revert to long-term values, consistent with normal return on investment over an assumed competitive advantage period. The *Decision-tree* valuation model allows investors to value the growth and abandonment options of firms, who can respond to high- and low-growth environments by altering investment policy. In addition, the models are equally applicable to profitable and loss-making firms, given that they include separate estimates of revenue growth and profit margin. This contrasts with textbook valuation models which typically rely on an estimate of earnings growth.

The modelling techniques allow investors to quantify the proportion of equity value not captured by the present value of expected future cash flows. This is especially important for the high-growth, high-volatility Technology and Healthcare sectors. Firms in these sectors are characterised by high growth, a high level of innovation and significant probability of failure. These firms are expected to have a significantly higher frequency of losses than firms in other industries. Hence, the value of the firms' abandonment option is likely to be greater. Further, the heightened volatility of revenue and margin growth means that their growth options also have above-average value, given that investment policy is expected to change in response to feedback regarding the firm's growth prospects.

This issue is relevant for equity analysts and portfolio managers who still largely rely on multiples-based valuation and *Discounted Cash Flows*. These valuation techniques dominate current practice despite the lack of evidence that the use of earnings multiples enhances performance and an emerging view that *DCF* valuations underestimate the value of assets with embedded options. It is particularly important because technology stocks comprise a significant percentage of the market capitalization of listed stocks. Of the S&P500, 83 stocks with a combined market capitalisation of US$1.4 trillion are classified as Information Technology stocks under the FTSE Global Industry Classification System (GICS©), which is 16 percent of the index. The S&P/ASX 300 has 16 stocks classified as Information Technology with a market capitalisation of A$2.3 billion, 0.4 percent of the index.

Application of the models resulted in significantly positive excess returns after controlling for factors associated with equity returns – market risk, size, the book-to-market ratio and momentum. I formed long-short portfolios by selecting stocks ranked according to value relative to price on 30 April each year from 1987-2004. For the full sample, long-short portfolios formed from the top and bottom deciles of this ranking earned excess monthly returns of up to 0.6 percent and excess annual returns of up to 8.2 percent. For portfolios formed on the basis of the top and bottom quintiles of stocks, excess monthly returns were up to 0.3 percent and excess annual returns reached 4.6 percent. Outperformance was most consistent for long-short portfolios formed from a sub-sample of small high market-to-book stocks, and there is no evidence of outperformance amongst portfolios formed from large high market-to-book stocks. This is consistent with the explanation of Lakonishok, Shleifer and Vishny (1994) for the value-glamour anomaly, that investors extrapolate past earnings growth for an unreasonably long competitive advantage period.

Excess returns remained even after controlling for three definitions of risk – portfolio volatility, Fama-French factors and default risk. Portfolios of stocks with high value/price ratios had significantly higher Sharpe ratios than portfolios with lower value/price ratios; and long-short portfolios had significantly positive intercept terms in four-factor regressions. Default risk is a concern, given that the valuation models typically identified small, low market-to-book stocks as undervalued and there is a strong association between size and credit ratings. However, the magnitude of the excess returns earned by long-short portfolios is significantly higher than the default risk premium required by debtholders.

In addition, the study enhances our understanding of sharemarket activity from 1998-2001, which was characterised by unusually high earnings multiples, a substantial increase in equity raisings and later claims that analyst research was tainted by the need to maintain corporate and investment banking relationships. The fall-out from this period included an $875 million settlement by ten broking houses with the Securities and Exchange Commission (SEC), the New York Stock Exchange (NYSE) and the National Association of Securities Dealers (NASD). But while there is substantial evidence that analyst research lacked objectivity for particular market segments, it is questionable whether this can be blamed for inflated equity prices in what is typically referred to as the 'tech bubble'.

For the sample analysed in this study, analysts' expectations for revenue growth and profit margins were not unusually high during this period, even for the Technology sector, nor was there unusual dispersion of those expectations. In contrast, the dispersion of fundamental value/price ratios increased significantly during this period. The result was that long-short portfolios formed as a result of those fundamental values typically earned negative returns during 1998-1999, the boom years for growth stocks. However, these losses were more than recovered during the two subsequent years. This evidence is inconsistent with the argument that analyst hype was a major contributor to inflated equity prices. But it is consistent with the argument that the sudden rise in equity prices was due to short sale restrictions (Ofek and Richardson, 2003), which would allow market prices to divert sufficiently from fundamentals for actively-managed funds to prosper.

The paper proceeds as follows. Section 2 summarises the evidence on valuation techniques in practice and the evidence that a material component of asset prices can be attributed to firms' embedded options. Section 3 presents the *DCF* and *Decision-tree* valuation techniques. Section 4 describes the sample and the association between market prices and theoretical values. Section 5 analyses the performance of investment portfolios formed on the basis of value relative to price and conclusions are presented in Section 6.

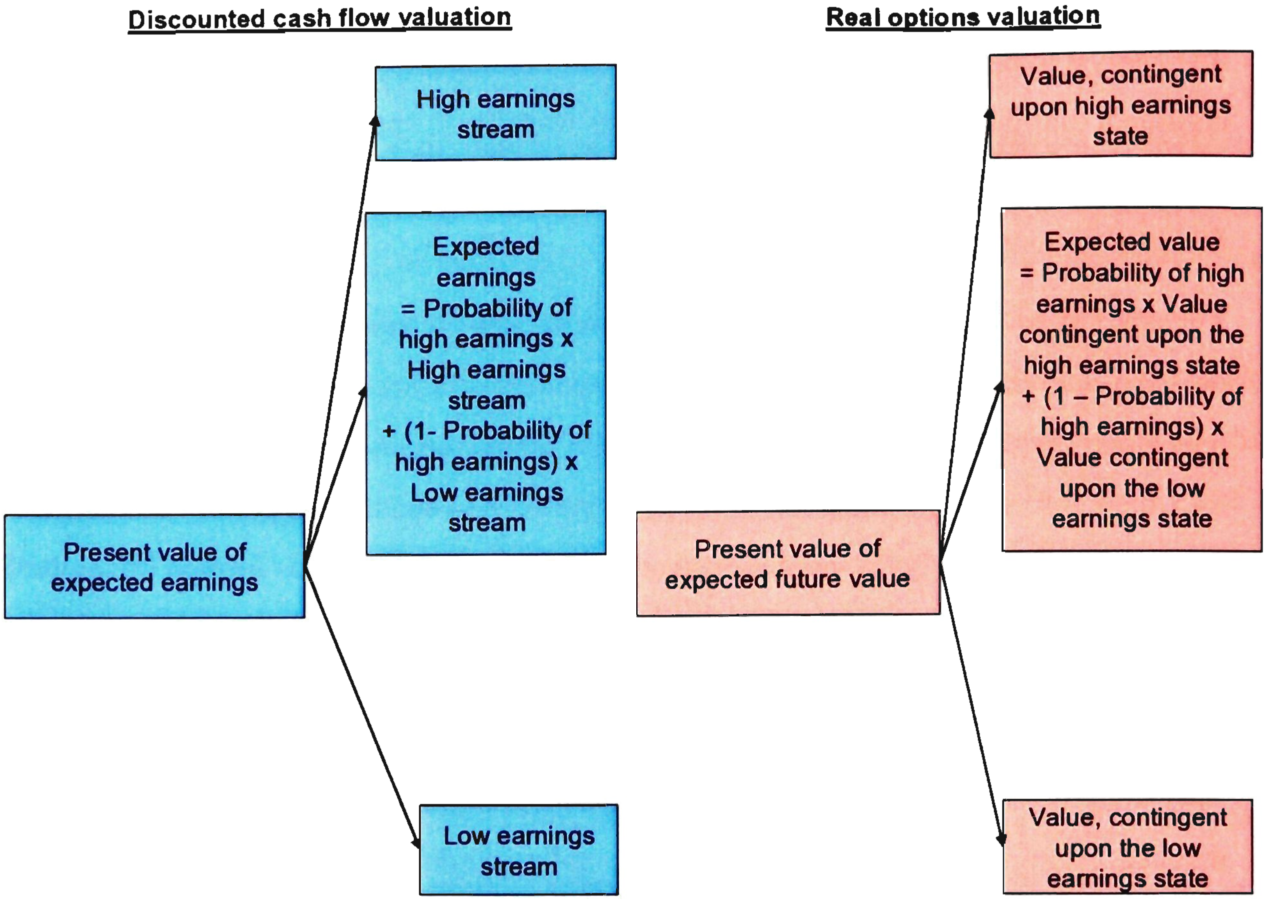
2 Empirical evidence on real options valuation

This study is motivated by the emerging use of real options valuation in corporate finance practice, its minimal use by equity analysts, and expanding evidence that market prices typically exceed the *Discounted Cash Flow* valuation of assets. It appears that equity analysts are overwhelmingly concerned with earnings forecasts, but perform valuations based on those forecasts in an almost arbitrary fashion. The glaring contrast of valuation methods used by these two groups suggests the need for further research into the usefulness of fundamental analysis for making investment decisions. This also motivates the estimation techniques and performance evaluation methods I use in this study. I use estimation techniques which can be implemented in practice, and evaluate their usefulness from the context of a portfolio manager.

The real options valuation of a project can be considered the value which includes management's options to change the size or scope of that project. By construction, it will exceed the *Discounted Cash Flow* value of that project. The valuation difference occurs because the *DCF* value is the present value of a series of expected cash flows. In contrast, a real options valuation computes project value as the expectation of the values associated with all possible cash flows. This difference is illustrated in Exhibit 2.1, for the simplest formulation where earnings can continue as a perpetual stream of either high or low cash flows.

Exhibit 2.1

Illustration of Real Options versus *Discounted Cash Flow* valuation



In the case where management can make strategic decisions in response to new information, the exercise of these options can increase the value of the project. In the situation represented above, this information is the level of the cash flow stream. Management's options could include an abandonment option, such as the sale or shutdown of the project, or a growth option, such as expanding production. In Section 3, the case envisaged is a series of options to either increase or decrease investment, in response to revenue growth which is above or below expectations.

2.1 Valuation techniques in practice

In corporate finance practice, the standard *Discounted Cash Flow* approach to valuation is gradually being supplemented with real options valuation. Graham and Harvey (2001) report that 27 percent of US corporations use real options analysis, based on a survey of 392 Chief Financial Officers. There is evidence of similar adoption in Australia, with Truong, Partington and Peat (2005) reporting that 32 percent of large, listed companies use real options analysis for valuation. These studies also report that net present value calculations are used in almost every major investment decision.

The predominant use in corporate finance of *DCF* valuation and increasing use of real options analysis stands in marked contrast to the valuation practice of equity analysts. The evidence suggests their valuations and recommendations are largely determined by earnings analysis and estimation of earnings multiples. Asquith, Mikhail and Au (2005) analysed 1,126 analyst reports of the top-rated US analysts according to *Institutional Investor*. They found that 99 percent of recommendations were justified on the basis of an earnings multiple, compared to just 13 percent for *DCF* methods. Demirakos, Strong and Walker (2004) analysed 104 research reports on 26 UK stocks in the beverages, electronics and pharmaceuticals sectors. They report that just 39 percent of reports included a *DCF* valuation, less than half the 89 percent which used earnings multiples.

This is consistent with the earlier evidence of Block (1999) and Bradshaw (2002). Block found that 46 percent of surveyed analysts *never* used present value techniques, even amongst sub-samples of MBA graduates and CFA Charterholders, groups specifically trained in *DCF* techniques. The results of Bradshaw (2002) show that at least 74 percent of target prices are the result of multiples analysis. In addition, at least 13 percent of target prices are derived without any reference to current price, and justified on the basis of growth, earnings surprise and industry-specific operating statistics. This is interesting as the empirical evidence of a positive association between earnings surprise and returns would support a short-term trading recommendation, rather than a target price usually made in relation to a 12-month holding period.

The overwhelming use of earnings multiples by analysts to justify recommendations or target prices can be justified if they lead to subsequent outperformance. However, there is evidence that analysts pay considerably more attention to forecasting earnings, than to the appropriate valuation based on those earnings. Previs, Bricker, Robinson and Young (1994) performed a content analysis of 479 analyst reports and find that discussion of income statement items dominate the analysis, with valuation a secondary consideration. Bradshaw (2002) finds that target prices are correlated with earnings and growth expectations. But there is no evidence that trading on the basis of target prices or recommendations results in superior investment performance (Bradshaw, 2004; Asquith et al, 2005). Instead, Bradshaw presents evidence that a residual income valuation based on those earnings forecasts is associated with subsequent abnormal returns.

This evidence establishes a prima facie case for the use of fundamental valuation techniques in making investment decisions, provided the valuation is performed appropriately. The *DCF* techniques used in corporate finance receive scant attention by the analyst community, despite the evidence that their preferred technique, multiples-based valuations, are not associated with subsequent outperformance. My primary motivation is to measure any outperformance associated with (1) a *DCF* model which incorporates assumptions regarding growth and margins which are bounded by economic theory; and (2) a *Decision-tree* model which incorporates an estimate of the value of embedded options.

An additional motivation for this research is the continued debate in the literature about whether the underperformance of growth stocks is attributable to their lower risk, or investors extrapolating past revenue growth for an unsustainable period, and consequently overpricing these stocks. The valuation models used in this study assume that growth and profit margins revert to long-term expected values over a period referred to as the competitive advantage period *(CAP)*. This is consistent with the argument that firms' competitive advantage is eroded over time, such that the expected long-run return on investment is equal to the cost of capital. The resulting portfolios are heavily weighted towards low market-to-book stocks, but this weighting is systematically reduced with an increase in the assumed competitive advantage period. This provides support for the contention that the outperformance of value stocks is due to investors under-estimating the rate at which competition erodes growth, rather than the result of some unspecified risk factor.

The relationship between returns, the market-to-book ratio and firm size is discussed in the results section. The remainder of Section 2 is devoted to empirical and theoretical evidence on real options valuation, which has been estimated in two ways: (1) indirectly, by inferring their value from market prices; and (2) directly, using an option pricing model.

2.2 Indirect valuation: Inferring option values from market prices

Berger, Ofek and Swary (1996) attribute a material portion of equity value to the equityholders' abandonment option. They document a median 11.5 percent difference between equity market value and the present value of cash flows for 7,102 firm years from 1984-1990. This premium is significantly associated with two estimates of liquidation value – book value and a variable they refer to as "excess exit value." Excess exit value is an estimate of the percentage difference between the expected exit value of equity and the present value of cash flows, where expected exit value = cash + 0.72 x receivables + 0.55 x inventory + 0.54 x fixed assets – payables – total debt. The coefficients on receivables, inventory and fixed assets were obtained by regressing exit value on noninventory current assets, inventories and fixed assets, all scaled by book value, for 157 asset sales.

From a series of regressions the authors report an association between the market value/present value premium and variables which should be associated with higher values for the abandonment option. They find a positive association between this premium and the ability to redeploy assets, the probability of financial distress and the alignment of manager and shareholder interests. Hence, they conclude that the premium of market price over present value is the market's estimate of the abandonment option.

However, the evidence from this indirect valuation cannot necessarily be interpreted as the value of the *abandonment* option, but rather the combined value of the firm's growth options and abandonment option. The proxies argued to be correlated with abandonment option value could also be correlated with the value of growth options. For example, firms with growth options are likely to have a relatively lower proportion of fixed assets and more intangible assets, and have a higher probability of financial distress if the level of growth is correlated with volatility.

In addition, Berger et al (1996) document that abandonment option value is highly sensitive to estimates of the terminal growth rate and the time at which the firm is assumed to enter its terminal growth state. However, the relationship between excess exit value and abandonment option value is insensitive to these parameters. This evidence is contrary to the theoretical implication that the more likely an abandonment option is to be exercised, the higher its value. Specifically, the abandonment option is less likely to be exercised the higher the terminal growth rate and the longer the period of extraordinary growth. Therefore, the strength of the relationship between excess exit value and abandonment option value should decline as these parameters are increased.

The present study extends on the contribution of Berger et al (1996) by directly estimating firms' option values using simulation techniques.

2.3 Direct valuation using an option pricing model

Recent literature has applied real options valuation to a variety of settings. For example, Schwartz and Moon (2000 and 2001) develop a real options valuation model for internet stocks, which forms the foundation for the *Decision-tree* model used in my study. In their first paper, Schwartz and Moon (2000) develop a valuation model in continuous time and apply a discrete-time version of the model to value Amazon.com using 100,000 simulations. They conclude that "even when the chance that a company may go bankrupt is real, if the initial growth rates are sufficiently high and if there is enough volatility in this growth over time, valuations can be what would otherwise appear to be unbelievably high (p.74)." They extend their modelling in Schwartz and Moon (2001), allowing for stochastic costs and future financing, as well as incorporating capital expenditure and depreciation. They then apply this version of the model to a valuation of eBay. Option pricing theory has also been used to model strategies for investment in technological innovations (Grenadier and Weiss, 1997) and to explain the firm life cycle (Bernardo and Chowdry, 2002).

Schwartz and Moon (2001) also modelled the relationship between volatility of expected sales growth and stock price volatility. They report that the model could value Amazon.com at its then market price of $76.125 if the standard deviation of expected sales growth equals 6 percent. However, this assumption implied price volatility of 182 percent, twice Amazon's historic volatility. This provides an indication of the likely dispersion between theoretical valuations and market prices. For the record, the share price of Amazon.com fell to $5.97 on 28 September 2001, but recovered to reach $59.91 on 16 October 2003.

There will be a material difference between theoretical valuations and market prices in any large-sample equity valuation study which relies on analyst forecast information. Regardless of the model used, the valuation is likely to rely on parameter estimates which, by construction, are significantly more stable than equity prices. While changes in share prices are an indication of changes in market expectations, these expectations are not immediately incorporated into databases of earnings forecasts and interest rates, nor are changes in systematic risk immediately reflected in computed beta estimates. So while the price of a stock can be used to infer market-wide expectations of underlying parameters, valuations based on a database of underlying parameters are liable to differ significantly from market prices. This will occur even if market prices immediately incorporate all price-sensitive information. The appropriate question for portfolio managers is, "Can the theoretical valuation be used to form investment portfolios which earn positive risk-adjusted returns?" This question motivates the research method I adopt, which involves forming investment portfolios on the basis of value relative to price. The use of this research method provides estimates of abnormal returns which are closest to those which portfolio managers could actually achieve. This is important in assessing whether the results are economically significant.

Despite the theoretical development of real options valuation models, there is little empirical evidence of their usefulness in making investment decisions. One example of an empirical study is the paper by Quigg (1993), in which a real options valuation model for land is evaluated. The author estimates the intrinsic and option value of 2,700 undeveloped properties in Seattle, which were sold from 1976-79. The study reports an average option premium of 6 percent, ranging from 1-30 percent for sub-samples, and implied annual standard deviation of prices of 19-28 percent. Using the option premium to explain sale prices in addition to intrinsic value yields additional explanatory power of about 2 percent. However, there is no large-sample evidence which measures the impact of incorporating volatility into theoretical equity valuations. This is an important contribution of my research.

3 Methodology

For a sample of stocks drawn from the S&P500 and NASDAQ Composite indices, I identify mispricing using a *DCF* valuation model and a *Decision-tree* valuation model. I consider a stock to be relatively undervalued the higher its value/price ratio compared to other stocks; and relatively overvalued the lower its value/price ratio. This direct approach to valuation requires me to estimate the distribution of future cash flows to equityholders, which I estimate using consensus earnings and sales forecasts, combined with historical data. In this section I outline these two valuation models, parameter estimation techniques and provide valuation examples using data from Microsoft. In Section 4 I describe the sample and the method used to test whether these valuation methods identify mispriced stocks, and present the results in Section 5.

A common criticism of *DCF* and multiples-based valuation techniques is that they cannot be applied to loss-making firms. This criticism was especially apparent during 2000-2001 when there were unusually high stock returns to loss-making firms. The valuation models presented here are not subject to this criticism, because they are equally applicable to profitable and loss-making firms. In forecasting future cash flows, I forecast revenue growth and the net profit margin, under the assumptions that both these parameters revert to long-term values that are consistent with economic theory. Specifically, I assume that revenue growth reverts to the product of the reinvestment rate and the required return to equityholders. This is consistent with the assumption that competition eventually reduces the expected abnormal returns on investment to zero. Further, I assume that the profit margin – the ratio of net profit to sales - will revert to a long-term sustainable level, which is also consistent with competition eroding abnormal profit margins. The justification for the profit margin assumption is discussed in more detail later. The discounted cash flow model is outlined in Sub-section 3.1

The additional information provided by the *Decision-tree* valuation model is the result of volatile revenue growth. In the *Decision-tree* valuation model, I simulate 1000 paths of revenue and earnings, adapting stochastic processes described in Schwartz and Moon (2001), and compute the valuation implied by each path. What I then refer to as the *Decision-tree* valuation is the mean of these 1000 valuations. These valuations are expected to exceed the *Discounted Cash Flow* valuations, because they incorporate the exercise of growth and abandonment options. The *DCF* valuation ignores the value that can be created via the firm's ability to change its reinvestment policy in response to new information. In other words, *DCF* valuation assumes that growth is independent of the investments made with reinvested earnings. If management invests additional capital in projects generating high earnings growth and reduces investment in low growth projects, the improved capital allocation amongst business units or products will result in realised growth exceeding expectations.

Throughout, I specifically refer to the *Decision-tree* valuation model rather than a real options valuation model. But I also refer to the difference between the *DCF* and *Decision-tree* values as the value of embedded options. In a setting in which parameter estimates could be made with a great deal of certainty, I would estimate real options valuations. But this involves estimating the market price of revenue growth, in order to simulate risk-neutral cash flows. This introduces an additional parameter to the valuation model, with an expected large standard error. Thus, I used *Decision-tree* valuations on the basis that there is likely to be less uncertainty associated with discounting nominal cash flows at a constant risk-adjusted discount rate, than discounting risk-neutral cash flows at the risk-free rate. This occurs because the lower discount rate used in real options valuation magnifies the impact on value of mis-estimating the market price of revenue growth. As is always the case in applying valuation techniques to a large sample of stocks, I have made a judgment as to which path-dependent valuation technique will introduce the most uncertainty into the valuation process – that which is technically inferior or that which is most affected by noisy parameter estimates.

The argument that improved capital allocation amongst high- and low-growth segments is valuable finds support in the corporate finance literature on the diversification discount. Recent research questions whether diversified firms really do trade at a discount to their break-up value, estimated using valuation multiples for comparable single-segment firms (Villalonga, 2004). But this research upholds an important explanation for the discounted value of certain firms, namely that a discount is applied to firms which overinvest in low-growth segments relative to high growth segments (Berger and Ofek, 1995; Ahn and Denis, 2004).

In contrast, the *Decision-tree* valuation model assumes that the firm invests additional funds in new projects subsequent to a period of strong earnings growth, consistent with the deployment of additional capital to high growth markets. Conversely, lower amounts of capital are allocated to low growth investments. Hence, the *Decision-tree* valuation model assumes a *dynamic investment policy*, in contrast to the implementation of a typical *DCF* model which assumes expected cash flows are the result of one *static set of investments*. Note that it is not the theory of present value analysis that causes under-estimation of value, but rather its implementation. That is, the expected cash flows incorporated into a *DCF* valuation should theoretically be the outcome of all possible investments, weighted according to their probability of occurrence. While this can be achieved via Monte Carlo simulation, this does not typically occur in practice. The *Decision-tree* valuation model is outlined in Sub-section 3.2.

The two equity valuation models can be summarised as follows:

1. The *Discounted Cash Flow* valuation (*DCF*) assumes that sales growth and the net profit margin revert to their long-term expected values over a period termed the competitive advantage period. The *DCF* valuation is described in detail in Sub-section 3.1.

2. The *Decision-tree* valuation (*DTV*) is the mean of 1000 valuations which result from the simulation of sales growth over the competitive advantage period. Hence, it incorporates additional value attributed to management's ability to reinvest additional income in high-growth states and reduce investment in low growth states. It also incorporates a profit margin which is positively correlated with revenue growth, but which also includes a random component. The *Decision-tree* valuation is described in detail in Sub-section 3.2.

Implementing the models requires the analyst to estimate 17 parameters, including 11 for the *DCF* valuation and an additional six for the *Decision-tree* valuation. In comparison to the valuation models presented in textbooks on investments, this appears to be a substantial increase on the number of parameters required for equity valuation. But it should be noted that all 11 parameters required for the *DCF* valuation are already required for any method of *DCF* valuation. The only reason that these may not appear in a valuation equation is that implicit assumptions are embedded in the model. Further, the additional six assumptions required for the *Decision-tree* valuation model are also already implicitly being made by investors and analysts. Those implementing *DCF* valuations are implicitly assuming that investment policy is independent of the distribution of future earnings, so that earnings above and below expectations have a symmetric impact on value. These points are considered in more detail in Sub-section 3.4.

3.1 Discounted cash flow valuation

I employ the following three-stage *DCF* model, where the three stages comprise an explicit forecast period of n years, a period of T years in which revenue growth and profit margins revert to long-term sustainable levels, followed by sustainable earnings growth into perpetuity. I refer to the period of $n + T$ years as the competitive advantage period (*CAP*). During the sustainable growth period, reinvestments are assumed to earn just the cost of equity capital, making the dividend decision during this stage irrelevant to the value of the stock. Note that this reinvestment assumption means that reinvested earnings earn a return commensurate with their risk. If these investments also involve debt financing, the total investment by the debt- and equityholders is expected to earn a return equal to the weighted-average cost of capital. The model is presented below as Exhibit 2.2, followed by its derivation.

Exhibit 2.2
***Discounted Cash Flow* valuation summary**

***DCF* valuation**

The *DCF* valuation is the present value of expected future dividends, where dividends are the product of sales per share (S), profit margin (m) and the dividend payout ratio (p), but cannot be negative. The three terms of the model correspond to the explicit forecast period (n years), the remainder of the competitive advantage period (T years), and the sustainable growth period (after year $n + T$).

$$DCF = \sum_{i=1}^{n} \frac{Max(p_i m_i S_i, 0)}{e^{r_e i}} + \sum_{i=n+1}^{n+T-1} \frac{Max\left(pm_i S_n e^{\sum_{i=n+1}^{n+T-1} g_i}, 0 \right)}{e^{r_e i}} + \frac{\overline{m} S_n e^{\sum_{i=n+1}^{n+T} g_i}}{r_e e^{r_e (n+T-1)}}$$

Revenue growth

Revenue growth (g) declines asymptotically to a long-term sustainable rate ($\overline{g}$), estimated as the product of the reinvestment rate ($1 - p$) and the cost of equity capital (r_e).

$$\begin{aligned} g_i &= e^{-\kappa} g_{i-1} + (1 - e^{-\kappa})\overline{g} \\ &= e^{-\kappa(i-n)}(g_n - \overline{g}) + \overline{g} \\ &= e^{-\kappa(i-n)}[g_n - (1-p)r_e] + (1-p)r_e \end{aligned}$$

Profit margin

Profit margin (m) declines asymptotically to a long-term sustainable level ($\overline{m}$), estimated with reference to established firms.

$$\begin{aligned} m_i &= e^{-\kappa} m_{i-1} + (1 - e^{-\kappa})\overline{m} \\ &= e^{-\kappa(i-n)}(m_n - \overline{m}) + \overline{m} \end{aligned}$$

Variable definitions

DCF	= discounted cash flow valuation of equity per share at time 0;
E_i	= forecast earnings in year i;
p_i	= dividend payout ratio in year i;
p	= dividend payout ratio from years $n + 1$ onwards;
g_i	= continuously-compounded sales growth in year i;
g_n	= continuously-compounded sales growth in year n (initial growth);
$\overline{g}$	= long-term sustainable growth rate in sales;
m_i	= net profit margin (earnings/sales) in year i;
m_n	= net profit margin in year n (initial margin);
$\overline{m}$	= long-term sustainable net profit margin;
S_n	= estimated sales per share in year n;
r_e	= continuously-compounded cost of equity capital; and
κ	= speed of adjustment parameter for sales growth and profit margin.

Incorporating the equations for revenue growth and profit margin into the valuation equation, the *DCF* valuation can be expressed as follows. Line one is the present value of expected dividends during the explicit forecast period, line two is the present value of expected dividends during the remainder of the competitive advantage period and line three is the present value of expected dividends during the sustainable growth period.

$$DCF = \sum_{i=1}^{n} \frac{p_i m_i S_i}{e^{r_e i}} + pS_n \sum_{i=n+1}^{n+T-1} \frac{\left[\overline{m} + e^{-\kappa(i-n)}(m_n - \overline{m})\right]\exp\left[\overline{g}(T-1) + (g_n - \overline{g})\sum_{i=n+1}^{n+T-1} e^{-\kappa(i-n)}\right]}{e^{r_e i}} + \overline{m}S_n \frac{\exp\left[\overline{g}T + (g_n - \overline{g})\sum_{i=n+1}^{n+T} e^{-\kappa(i-n)}\right]}{r_e e^{r_e(n+T-1)}} \qquad (2.1)$$

3.1.1 Model derivation

The model is derived from the dividend discount model of equity valuation, under the assumptions that both sales growth and profit margin will revert to long-term sustainable levels by the end of the competitive advantage period. It further assumes that the dividend payout ratio remains constant at some level p from years $n + 1$ to $n + T - 1$. Beyond this point, the assumption regarding dividend policy does not influence value, because additional investments are expected to earn just their cost of capital in perpetuity. In other words, the terminal value of $\frac{S_n \overline{m} e^{\sum_{i=n+1}^{n+T} g_i}}{r_e}$ is independent of the firm's reinvestment policy.

According to standard finance theory, the *DCF* value of equity (*DCF*) is the present value of expected future dividends, as presented below:

$$DCF = \sum_{i=1}^{\infty} \frac{D_i}{e^{r_e i}} = \sum_{i=1}^{n} \frac{D_i}{e^{r_e i}} + \sum_{i=n+1}^{n+T-1} \frac{D_i}{e^{r_e i}} + \sum_{i=n+T}^{\infty} \frac{D_i}{e^{r_e i}} \qquad (2.2)$$

where:

D_i = expected dividend per share in year i;

r_e = the continuously-compounded cost of equity capital;

n = the number of years of the explicit forecast period; and

$n + T$ = the number of years of the competitive advantage period.

Dividends can be expressed as the product of expected earnings per share *(E)* and the dividend payout ratio (p), and earnings per share can be expressed as the product of sales and the net profit margin, implying that:

$$\begin{aligned} DCF &= \sum_{i=1}^{n} \frac{p_i E_i}{e^{r_e i}} + \sum_{i=n+1}^{n+T-1} \frac{p_i E_i}{e^{r_e i}} + \sum_{i=n+T}^{\infty} \frac{p_i E_i}{e^{r_e i}} \\ &= \sum_{i=1}^{n} \frac{p_i m_i S_i}{e^{r_e i}} + \sum_{i=n+1}^{n+T-1} \frac{p_i m_i S_i}{e^{r_e i}} + \sum_{i=n+T}^{\infty} \frac{p_i m_i S_i}{e^{r_e i}} \end{aligned} \qquad (2.3)$$

Further, sales in year i (S_i) can be expressed as the product of sales in the previous period (S_{i-1}) and e^{g_i} where g_i is the continuously-compounded sales growth in period i:

$$DCF = \sum_{i=1}^{n} \frac{p_i m_i S_i}{e^{r_e i}} + \sum_{i=n+1}^{n+T-1} \frac{p_i m_i S_{i-1} e^{g_i}}{e^{r_e i}} + \sum_{i=n+T}^{\infty} \frac{p_i m_i S_{i-1} e^{g_i}}{e^{r_e i}} \tag{2.4}$$

Now I incorporate assumptions which restrict the potential values for profit margin and sales growth. The relationship between these assumptions, revenue growth and margin growth is analysed in more detail in the section below. The paper can be read without reference to the discussion in that section. First, I incorporate the assumption that in the sustainable growth period (1) the return on equity on new investments just equals the cost of equity capital; and (2) the firm has exhausted all opportunities to achieve economies of scale, implying that fixed costs rise at a constant percentage of sales.

The impact of the first assumption is that, in the sustainable growth period, earnings growth is equal to the product of the reinvestment rate $(1-p)$ and the required return to equityholders r_e, a constant. The impact of the second assumption is that long-term sales growth is equal to long-term earnings growth, because earnings growth no longer benefits from operating leverage. Under the assumption that initial revenue growth (at the end of the explicit forecast) is expected to revert asymptotically to its long-term sustainable level over the subsequent T years, we have the following:

$$g_i = e^{-\kappa} g_{i-1} + \left(1-e^{-\kappa}\right)\bar{g} = e^{-\kappa(i-n)}\left(g_n - \bar{g}\right) + \bar{g} = e^{-\kappa(i-n)}\left[g_n - (1-p)r_e\right] + (1-p)r_e \tag{2.5}$$

The other impact of the second assumption, that the firm has exhausted all economies of scale, is that there is no expected growth in the profit margin in the sustainable growth period.

The impact of the first assumption is that, by the end of the competitive advantage period, expected margin growth is zero. Margin growth can then be modelled under the assumption that the initial margin (m_n) is expected to revert to its long-term sustainable level ($\overline{m}$) over the competitive advantage period.

This involves the joint assumption that asset turnover and leverage revert to long-term sustainable levels. Theoretically, firms within the same industry could earn comparable returns on new equity investment, but with different margins, asset turnover and leverage, as shown by a typical *DuPont ROE* breakdown (*ROE* = *Margin* x *Turnover* x *Leverage*). However, there is no reason to expect this to occur in equilibrium. First, there is a theoretical optimal capital structure for these firms, based on the volatility of their operational cash flows. Second, the abnormal returns to target shareholders from takeovers suggest that assets are transferred to users who can operating them most efficiently. Asset turnover is typically considered a measure of efficiency, so we have reason to believe there is a long-term sustainable asset turnover for the industry. This leads to the assumption that industry profit margins will converge to long-term sustainable levels.

If the process by which the expected profit margin reverts to a long-term expected value is the same as that which applies to revenue growth, we have the following:

$$m_i = e^{-\kappa} m_{i-1} + \left(1 - e^{-\kappa}\right)\overline{m} = e^{-\kappa(i-n)}\left(m_n - \overline{m}\right) + \overline{m} \tag{2.6}$$

Incorporating these expressions for sales growth and profit margin into the valuation, the equation becomes:

$$DCF = \sum_{i=1}^{n} \frac{p_i m_i S_i}{e^{r_e i}} + \sum_{i=n+1}^{n+T-1} \frac{p_i m_i S_n e^{\sum_{i=n+1}^{n+T-1} g_i}}{e^{r_e i}} + \sum_{i=n+T}^{\infty} \frac{p_i \overline{m} S_n e^{\sum_{i=n+1}^{n+T} g_i}}{e^{r_e i}} \tag{2.7}$$

where:

$$g_i = e^{-\kappa} g_{i-1} + \left(1 - e^{-\kappa}\right)\overline{g} = e^{-\kappa(i-n)}\left(g_n - \overline{g}\right) + \overline{g} = e^{-\kappa(i-n)}\left[g_n - (1-p)r_e\right] + (1-p)r_e$$

$$m_i = e^{-\kappa} m_{i-1} + \left(1 - e^{-\kappa}\right)\overline{m} = e^{-\kappa(i-n)}\left(m_n - \overline{m}\right) + \overline{m}$$

Finally, the combined impact of assuming constant growth in perpetuity and normal returns on equity investment, means that the terminal value can be computed. At the end of year (n + T – 1), the firm reinvests a percentage (1 – p) of its earnings $m_i S_n e^{\sum_{i=n+1}^{n+T-1} g_i}$. Earnings growth can be expressed as the product of the reinvestment rate (1 – p) and the return on equity on new investments (*ROE*). The assumption of the model is that, by the end of the competitive advantage period, investments earn just the cost of capital (r_e). I further assume that, in the sustainable growth period, fixed costs are a constant percentage of sales, which implies that sales growth equals earnings growth. Under these assumptions, the following holds:

$$\sum_{i=n+T}^{\infty} \frac{p\overline{m}S_n e^{\sum_{i=n+1}^{n+T} g_i}}{e^{r_e i}} = \frac{p\overline{m}S_n e^{\sum_{i=n+1}^{n+T} g_i}}{\left[r_e - \overline{g}\right] e^{r_e (n+T-1)}}$$
$$= \frac{p\overline{m}S_n e^{\sum_{i=n+1}^{n+T} g_i}}{\left[r_e - (1-p) r_e\right] e^{r_e (n+T-1)}}$$
$$= \frac{p\overline{m}S_n e^{\sum_{i=n+1}^{n+T} g_i}}{p r_e e^{r_e (n+T-1)}}$$
$$= \frac{\overline{m}S_n e^{\sum_{i=n+1}^{n+T} g_i}}{r_e e^{r_e (n+T-1)}} \tag{2.8}$$

Hence, the valuation takes the following form, which appears above as Equation 2.1:

$$DCF = \sum_{i=1}^{n} \frac{p_i m_i S_i}{e^{r_e i}} + \sum_{i=n+1}^{n+T-1} \frac{p m_i S_n e^{\sum_{i=n+1}^{n+T-1} g_i}}{e^{r_e i}} + \frac{\overline{m} S_n e^{\sum_{i=n+1}^{n+T} g_i}}{r_e e^{r_e (n+T-1)}} \tag{2.9}$$

where:

$$g_i = e^{-\kappa} g_{i-1} + \left(1 - e^{-\kappa}\right)\overline{g} = e^{-\kappa(i-n)}\left(g_n - \overline{g}\right) + \overline{g} = e^{-\kappa(i-n)}\left[g_n - (1-p) r_e\right] + (1-p) r_e$$

$$m_i = e^{-\kappa} m_{i-1} + \left(1 - e^{-\kappa}\right)\overline{m} = e^{-\kappa(i-n)}\left(m_n - \overline{m}\right) + \overline{m}$$

The exhibit below summarises the assumptions used in the *DCF* valuations, and how these are incorporated into the model. In the text which follows, I justify these assumptions by modelling the relationship between sales growth, earnings growth and margin growth, as implied by the overriding assumption that long-run expected returns on investment just equal the cost of capital.

Exhibit 2.3

Economic assumptions underlying the *Discounted Cash Flow* valuation and their impact on the valuation equation

Assumption and implication	**Modelling**	***DCF* value**
Theoretical value is the present value of expected future dividends		$DCF=\sum_{i=1}^{\infty}\frac{D_i}{e^{r_e i}}=\sum_{i=1}^{n}\frac{D_i}{e^{r_e i}}+\sum_{i=n+1}^{n+T-1}\frac{D_i}{e^{r_e i}}+\sum_{i=n+T}^{\infty}\frac{D_i}{e^{r_e i}}$
Expected dividends = expected earnings per share times the dividend payout ratio; Earnings per share = Sales per share times the profit margin	$D_i=p_iE_i=p_im_iS_i$	$DCF=\sum_{i=1}^{n}\frac{p_im_iS_i}{e^{r_e i}}+\sum_{i=n+1}^{n+T-1}\frac{p_im_iS_{i-1}e^{g_i}}{e^{r_e i}}+\sum_{i=n+T}^{\infty}\frac{p_im_iS_{i-1}e^{g_i}}{e^{r_e i}}$
Expected sales growth reverts to a long-term value over the competitive advantage period.	$g_i^r=e^{-\kappa}g_{i-1}^r+\left(1-e^{-\kappa}\right)\overline{g}$	$DCF=\sum_{i=1}^{n}\frac{p_im_iS_i}{e^{r_e i}}+\sum_{i=n+1}^{n+T-1}\frac{p_im_iS_ne^{\sum_{i=n+1}^{n+T-1}g_i}}{e^{r_e i}}+\frac{pm_{n+T}S_ne^{\sum_{i=n+1}^{n+T}g_i}}{\left(r_e-\overline{g}\right)e^{r_e(n+T-1)}}$
In the sustainable growth period, fixed costs rise at a constant percentage of sales ⇒ margin growth = zero ⇒ margin reverts to a long-term value; & revenue growth = earnings growth	$m_i=e^{-\kappa}m_{i-1}+\left(1-e^{-\kappa}\right)\overline{m}$ $g_i^e=g_i^r+g_i^m=g_i^r$	$DCF=\sum_{i=1}^{n}\frac{p_im_iS_i}{e^{r_e i}}+\sum_{i=n+1}^{n+T-1}\frac{p_im_iS_ne^{\sum_{i=n+1}^{n+T-1}g_i}}{e^{r_e i}}+\frac{p\overline{m}S_ne^{\sum_{i=n+1}^{n+T}g_i}}{\left(r_e-\overline{g}\right)e^{r_e(n+T-1)}}$
In the sustainable growth period, reinvested earnings earn the cost of equity capital ⇒ earnings growth = reinvestment rate times required return to equityholders	$g_i^e=g_i^r=(1-p)ROE=(1-p)r_e$	$DCF=\sum_{i=1}^{n}\frac{p_im_iS_i}{e^{r_e i}}+\sum_{i=n+1}^{n+T-1}\frac{p_im_iS_ne^{\sum_{i=n+1}^{n+T-1}g_i}}{e^{r_e i}}+\frac{\overline{m}S_ne^{\sum_{i=n+1}^{n+T}g_i}}{r_ee^{r_e(n+T-1)}}$

3.1.2 Assumptions underlying the DCF valuation

The estimate of long-term growth in sales per share ($\bar{g}$) relies on two assumptions which are drawn from economic theory. First, the long-term return on equity (*ROE*) on new investments is equal to the required return to equityholders (r_e) (which is equivalent to assuming that total returns to debt- and equityholders equal the weighted average cost of capital). This is consistent with economic theory which contends that competition will erode expected abnormal returns, where barriers to entry cannot be sustained indefinitely. Second, fixed costs will approximate a constant percentage of sales when the firm is in a mature state. This is consistent with economic theory which suggests that firms can achieve economies of scale only to a certain level. For example, fixed costs like head office expenses, replacement capital expenditure and wages provide operating leverage, such that growth in sales leads to disproportionate growth in earnings. Financial leverage provides a fixed cost in the form of interest payments which has the same effect. For unexpected sales growth, operating and financial leverage have the same impact on earnings growth relative to sales growth. But in the case of *expected* sales growth, they have little impact. This argument is outlined via the following example. I then provide an algebraic model of long-term growth which equates long-term sales and earnings growth to the product of the reinvestment rate and the required return to equityholders.

Consider the case of an all-equity financed firm worth \$100 million, expected sales are \$200 million, while expected earnings are \$10 million, due to \$90 million of fixed costs and \$100 million of variable costs. The firm pays no tax. Say the firm reinvests 50 percent of earnings in new projects which generate sales per dollar invested consistent with existing assets. Sales are expected to rise to \$210 million, providing sales growth of 5 percent. In the case where the firm is not in its perpetual growth state, and does not need to incur additional fixed costs, earnings rise by 50 percent to \$15 million. This occurs because the asset turnover (sales/assets) remains constant at 2 times, resulting in sales of \$210 million; variable costs/sales remains constant at 50 percent, resulting in variable costs of \$105 million; total costs are now \$195 million resulting in earnings of \$15 million. In sum, in the case where there is no growth in fixed costs with an increase in the size of the firm, earnings per share grow at a faster rate than sales per share.

Contrast this with the case in which the new project has the same proportion of fixed and variable costs as the existing assets. In this case, fixed costs rise by 5 percent to \$94.5 million, which flows through to earnings of just \$10.5 million, a rise of just 5 percent. Hence, in the case where fixed costs rise at the same rate as variable costs, earnings grow at the same rate as sales. These two cases are summarised in Exhibit 2.4, followed by a derivation of the relationship between sales growth, earnings growth and fixed costs for the general case.

Exhibit 2.4
Example of the relationship between fixed costs, revenue growth and earnings growth

	Year 0	Year 1 (No growth in fixed costs)	Year 1 (Fixed costs increase with sales)
Sales	200	210	210
Fixed costs	90	90	94.5
Variable costs	100	105	105
Total costs	190	195	199.5
Earnings	10	15	10.5
Equity = Assets (start)	100	105	105
Sales/Assets	2	2	2
Reinvestment rate	50%		
Reinvested earnings	5		
Sales growth		5%	5%
Earnings growth		50%	5%

The relationship between sales growth, earnings growth and growth in fixed costs can be derived for the general case. In a discrete setting, say we define earnings in year *i* as follows:

$$NPAT_i = [Sales_i(1-\gamma) - F_i][1-\tau] \quad (2.10)$$

where:

$NPAT_i$ = net profit after tax in year *i*;

F_i = fixed costs in year *i*;

$Sales_i$ = sales in year *i*;

γ = variable costs as a proportion of sales; and

τ = the corporate tax rate.

Earnings growth in year *i* can then be expressed as:

$$\begin{aligned} g_i^e &= \ln\left\{\frac{[Sales_i(1-\gamma) - F_i][1-\tau]}{[Sales_{i-1}(1-\gamma) - F_{i-1}][1-\tau]}\right\} \\ &= \ln\left\{\frac{Sales_i(1-\gamma) - F_i}{Sales_{i-1}(1-\gamma) - F_{i-1}}\right\} \end{aligned} \quad (2.11)$$

where:

g_i^e = earnings growth in year *i*.

Factorising the numerator and denominator of the equation, we can express earnings as the sum of revenue growth and margin growth:

$$g_i^e = \ln\left\{\frac{Sales_i\left[(1-\gamma)-{F_i}/{Sales_i}\right]}{Sales_{i-1}\left[(1-\gamma)-{F_{i-1}}/{Sales_{i-1}}\right]}\right\}$$

$$= \ln\left[\frac{Sales_i}{Sales_{i-1}}\right] + \ln\left[\frac{(1-\gamma)-{F_i}/{Sales_i}}{(1-\gamma)-{F_{i-1}}/{Sales_{i-1}}}\right]$$

$$= \ln\left[\frac{Sales_i}{Sales_{i-1}}\right] + \ln\left[\frac{\left[Sales_i(1-\gamma)-F_i\right]/{Sales_i}}{\left[Sales_{i-1}(1-\gamma)-F_{i-1}\right]/{Sales_{i-1}}}\right] \qquad (2.12)$$

$$\ln\left[\frac{Sales_i}{Sales_{i-1}}\right] + \ln\left[\frac{{E_i}/{Sales_i}}{{E_{i-1}}/{Sales_{i-1}}}\right]$$

$$= g_i^r + g_i^m$$

where:

g_i^e = earnings growth in year i;

g_i^r = sales growth in year i; and

g_i^m = margin growth in year i.

Furthermore, the following equations show the following relationship between earnings growth, revenue growth and the growth in fixed costs. Where revenue growth exceeds the growth in fixed costs, as occurs when economies of scale are present, margin growth will be positive, so earnings growth exceeds revenue growth. In contrast, where revenue growth is less than the growth in fixed costs, as occurs, say when the firm signs a long-term lease or makes significant capital expenditure in a low-growth market, margin growth will be negative, so earnings growth is less than revenue growth.

The second line of the above series of equations states:

$$g_i^e = \ln\left[\frac{Sales_i}{Sales_{i-1}}\right] + \ln\left[\frac{(1-\gamma)-{F_i}/{Sales_i}}{(1-\gamma)-{F_{i-1}}/{Sales_{i-1}}}\right] \qquad (2.13)$$

From this equation, we can represent earnings growth as a function of the growth in revenue and fixed costs, as follows:

$$g_i^e = g_i^r + \ln\left[\frac{(1-\gamma) - \dfrac{F_{i-1}e^{g_i^F}}{Sales_{i-1}e^{g_i^r}}}{(1-\gamma) - \dfrac{F_{i-1}}{Sales_{i-1}}}\right]$$
$$= g_i^r + \ln\left[\frac{(1-\gamma) - \dfrac{F_{i-1}}{Sales_{i-1}}e^{(g_i^F - g_i^r)}}{(1-\gamma) - \dfrac{F_{i-1}}{Sales_{i-1}}}\right] \tag{2.14}$$

where:

g_i^F = growth in fixed costs.

The above equation presents the general case, where fixed costs can increase to any degree with an increase in the scale of the firm's operations.

At one extreme, sales growth is accompanied by no growth in fixed costs. In this instance, earnings growth is given by the following equation, which implies that the higher the fixed costs relative to sales, the stronger the relationship between earnings growth and revenue growth:

$$g_i^e = g_i^r + \ln\left[\frac{(1-\gamma) - \dfrac{F_{i-1}}{Sales_{i-1}e^{g_i^r}}}{(1-\gamma) - \dfrac{F_{i-1}}{Sales_{i-1}}}\right] \tag{2.15}$$

In the situation where fixed costs grow at the same rate as sales, there is no change in operating margin, so that earnings growth equates to revenue growth, as the following shows:

$$g_i^e = g_i^r + \ln\left[\frac{(1-\gamma) - \dfrac{F_{i-1}}{Sales_{i-1}}e^{(g_i^F - g_i^r)}}{(1-\gamma) - \dfrac{F_{i-1}}{Sales_{i-1}}}\right]$$
$$= g_i^r + \ln\left[\frac{(1-\gamma) - \dfrac{F_{i-1}}{Sales_{i-1}}}{(1-\gamma) - \dfrac{F_{i-1}}{Sales_{i-1}}}\right] \tag{2.16}$$
$$= g_i^r$$

The relationship between sales growth and earnings growth, according to the above equations is summarised in the exhibit below.

Exhibit 2.5
Modelling the relationship between fixed costs, revenue growth and margin growth

General case	Fixed costs remain constant	Fixed costs increase in proportion to sales
$g_i^e = g_i^r + g_i^m$ $= g_i^r + \ln\left[\dfrac{(1-\gamma) - \dfrac{F_{i-1}}{Sales_{i-1}} e^{(g_i^F - g_i^r)}}{(1-\gamma) - \dfrac{F_{i-1}}{Sales_{i-1}}}\right]$ $= \ln\left[\dfrac{e^{g_i^r}(1-\gamma) - \dfrac{F_{i-1}}{Sales_{i-1}} e^{g_i^F}}{(1-\gamma) - \dfrac{F_{i-1}}{Sales_{i-1}}}\right]$	$g_i^e = g_i^r + g_i^m$ $= g_i^r + \ln\left[\dfrac{(1-\gamma) - \dfrac{F_{i-1}}{Sales_{i-1} e^{g_i^r}}}{(1-\gamma) - \dfrac{F_{i-1}}{Sales_{i-1}}}\right]$ $= \ln\left[\dfrac{e^{g_i^r}(1-\gamma) - \dfrac{F_{i-1}}{Sales_{i-1}}}{(1-\gamma) - \dfrac{F_{i-1}}{Sales_{i-1}}}\right]$	$g_i^e = g_i^r + g_i^m$ $= g_i^r + g_i^m$

Now, the relevant question is which set of assumptions apply to the firm in the perpetual growth state. My assumption is that, at the end of the competitive advantage period, fixed costs rise in proportion to sales, which is equivalent to the statement common to microeconomics texts "in the long run, all costs are variable". Importantly, this assumption only applies during the sustainable growth period. During the competitive advantage period, earnings growth still benefits from operating leverage, consistent with the general case presented in the exhibit above. This is implemented via the margin assumption. Recall that I estimate earnings per share as the product of sales and the profit margin:

$$E_i = S_i m_i \tag{2.17}$$

Sales per share in period *i* is the product of the previous year's sales and an exponential growth factor assuming revenue growth of g_i^r, which implies that:

$$E_i = S_{i-1} m_i e^{g_i^r} \tag{2.18}$$

We can then express earnings per share growth as the sum of revenue growth and growth in the profit margin, derived as follows:

$$\begin{aligned} &\frac{E_i}{E_{i-1}} = \frac{S_{i-1}}{E_{i-1}} m_i e^{g_i^r} \\ &\Rightarrow \frac{E_i}{E_{i-1}} = \frac{m_i}{m_{i-1}} e^{g_i^r} \\ &\Rightarrow \ln\left(\frac{E_i}{E_{i-1}}\right) = \ln\left[\frac{m_i}{m_{i-1}} e^{g_i^r}\right] \\ &\Rightarrow g_i^e = g_i^r + g_i^m \end{aligned} \tag{2.19}$$

where:

g_i^e = earnings per share growth in year *i*;

g_i^r = sales per share growth in year *i*; and

g_i^m = margin growth in year *i*.

The assumption underlying the valuations in this paper is that changes in margins are deterministic, and revert to long-term estimated values over the competitive advantage period. It is possible to introduce uncertainty into the estimated profit margin. However, this adds one more parameter which requires estimation, which increases the noise underlying equity values and makes it more difficult to evaluate the merits of the analysis for portfolio management. In the situation assumed here, that changes in the profit margin are deterministic, we can make the further substitution that:

$$m_i = e^{-\kappa} m_{i-1} + \left(1 - e^{-\kappa}\right)\overline{m}$$

which implies that:

$$\begin{aligned} g_i^e &= g_i^r + g_i^m \\ &= g_i^r + \ln\left[e^{-\kappa} + \left(1 - e^{-\kappa}\right)\frac{\overline{m}}{m_{i-1}} \right] \end{aligned} \qquad (2.20)$$

Hence, in the case where the firm has reached its steady state (so $m_{i-1} = \overline{m}$), growth in earnings and sales are equal. In the case where the margin is increasing, consistent with the firm achieving economies of scale, earnings growth exceeds sales growth; and where the margin is being eroded through competition, earnings growth is less than sales growth. This is equivalent to the case where the firm earns what analysts typically refer to as "low-quality growth" where revenue growth is achieved at the expense of lower returns on investment.

3.1.4 Example: Discounted Cash Flow valuation of Microsoft

At this point, it is worthwhile to illustrate how the *DCF* model is implemented. I perform a *DCF* valuation of Microsoft, as well as a *Decision-tree* valuation, which I summarise later. This illustration shows that implementing a rigorous *DCF* valuation technique requires little additional resources and could easily replace the use of arbitrary price-earnings multiples in practice. Again, if price-earnings valuations were associated with superior investment performance, this would be unnecessary. But the evidence cited in Section 2 showed this was not the case, so there is justification for analysts to invest in more sophisticated models.

At 14 June 2005, Datastream reported that Microsoft was priced at $25.31 and had consensus earnings forecasts of $1.29, 1.40 and 1.60 per share over the next three years, from its previous initial earnings of \$1.26. The consensus sales forecasts were \$3.67, 3.98 and 4.39 per share, compared to the last reported sales of \$3.39 per share. This data, from an explicit forecast period of three years and one year of historical data, provides four estimates of Microsoft's profit margin and three estimates of sales growth. The average margin over this period is 36.15 percent, while the average sales growth is 8.66 percent. Two consensus dividend forecasts are available, \$3.31 in forecast year 1, including a special dividend of \$3.00, and \$0.32 in forecast year 2, while dividends of \$0.16 were paid in the last financial year. This data implies an average dividend payout ratio of 97.33 percent, over the explicit forecast period and last year of historical data. However, applying the constraint that the payout ratio cannot exceed one for the purposes of estimating p, the average becomes p = 45.13 percent.

Further, Datastream reports than Microsoft has an equity beta of 1.28 and that the yield on 10-year Government bonds is 4.37 percent. If we assume a market risk premium of 6 percent, the discrete period cost of equity capital for Microsoft, according to the Capital Asset Pricing Model (CAPM) is 12.05 percent, and the continuously-compounded rate is 11.38 percent. Note that, for convenience, I have used the Datastream beta estimate rather than the beta estimate computed under the method described in Sub-section 3.1.2.

From the 173 technology firms in the dataset at 30 April 2004, I estimate the long-term profit margin for Microsoft at 8.60 percent. This is the mean estimate of the average profit margin over time for technology firms with a reporting history of at least five years. For the purposes of the example, I have assumed a competitive advantage period of 30 years, which implies that the speed of adjustment parameter is 0.2588 $\left(\kappa = \frac{-\ln 0.001}{27} = 0.2588\right)$.

In sum, from the publicly-available information on earnings and dividends, and from the assumption that the competitive advantage period is 30 years, we have the following parameters to estimate the *DCF* value for Microsoft:

Exhibit 2.6
Assumptions underlying the *Discounted Cash Flow* valuation of Microsoft

Parameter	Symbol	0	1	2	3	Initial	Long-term
Earnings margin	m	0.3719	0.3514	0.3538	0.3687	**0.3615**	**0.0860**
Sales growth	g		0.0801	0.0821	0.0976	**0.0866**	**0.0661**
Dividend payout ratio	p	0.1270	2.5659	0.2270	0.4513	**0.4513**	**0.4513**
Cost of equity	r_e		0.1138	0.1138	0.1138	**0.1138**	**0.1138**
Earnings per share	E		1.29	1.41	1.62		
Dividends per share	D	0.16	**3.31**	**0.32**	**1.58**		
Speed of adjustment	κ						**0.2588**

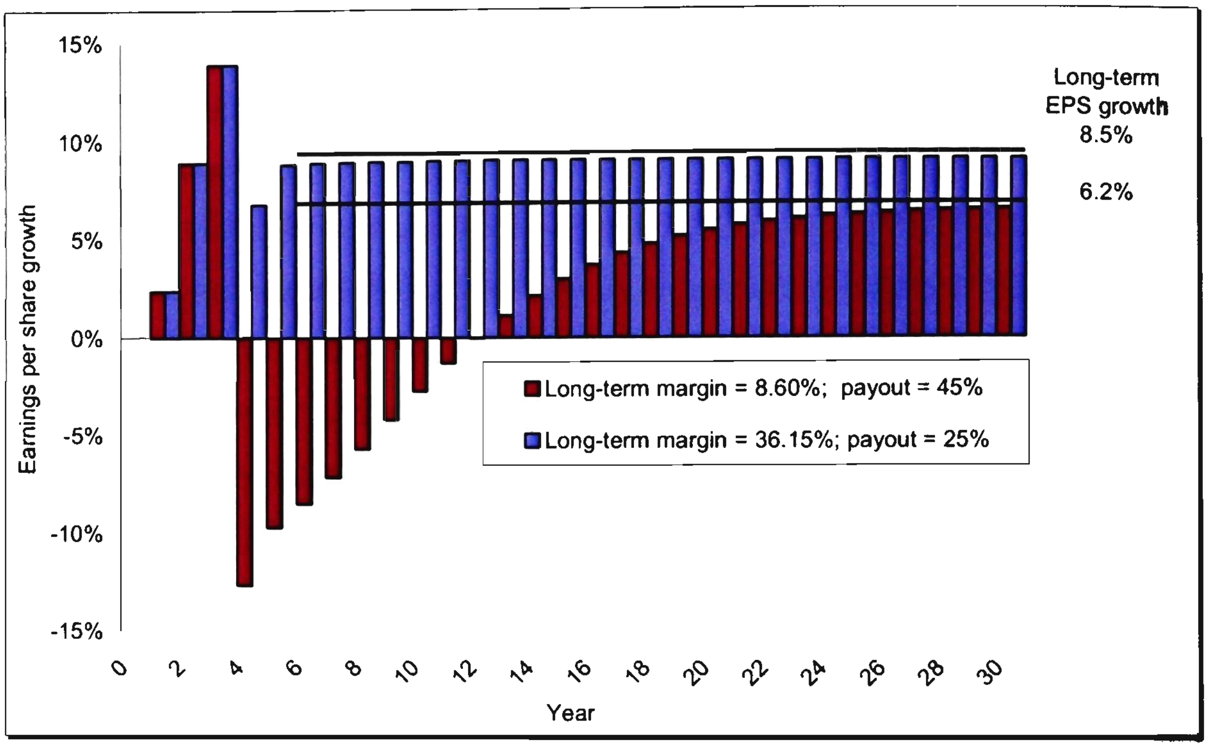
The *DCF* valuation implied by these parameter estimates is \$6.91, which is 73 percent below the market price of \$25.31. Clearly, the market price incorporates higher growth in cash flows than forecast by the model, most likely due to the assumption of a higher long-term profit margin and reinvestment rate. However, even if we maintain the profit margin at the initial level of 36.15 percent and assume a dividend payout ratio of 25 percent, the *DCF* valuation reaches just \$13.31, still 47 percent below the share price.

The earnings per share growth underlying these two valuations is illustrated in Figure 2.1. In the case where the long-term margin is estimated at 8.6 percent and the initial dividend payout ratio is estimated at 45.13 percent, EPS growth in year 4 is sharply negative. This occurs because the rapidly declining profit margin more than offsets the forecast 8.12 percent expected sales growth. However, by the end of year 13, EPS growth is again positive, because of the less rapid decline in the profit margin. In contrast, in the case where the profit margin is maintained at 36.15 percent, EPS growth is positive throughout and equal to sales growth for year 5 onwards. The difference in year 4 is due to the fact that the profit margin in year 3 of 36.87 percent exceeds the initial profit margin estimate of 36.15 percent.

The figure also illustrates that EPS growth asymptotically approaches the product of the reinvestment rate and the required return on equity. In the first case, the reinvestment rate of 54.87 percent and required return on equity of 11.38 percent imply long-term EPS growth of 6.24 percent. This reaches 8.53 percent for the second case, which assumes a reinvestment rate of 75 percent. Hence, the figure illustrates the two most important economic assumptions underlying the valuations in this paper: (1) that the expected long-run return on equity on new investments asymptotically reaches the cost of equity capital over the competitive advantage period; and (2) it reaches this expected long-run value via an expected profit margin which reaches its sustainable level over the same period.

Figure 2.1
EPS growth underlying the illustrative *DCF* valuation of Microsoft

Figure 2.1 presents the expected growth in earnings per share for Microsoft under two sets of assumptions. First, over forecast years 4 to 30, I assume that the profit margin declines from an initial value of 36.15 percent to a long-term expected value of 8.60 percent, and the dividend payout ratio remains constant at 45.13 percent. I assume that sales growth declines from an initial value of 8.66 percent to a long-term estimate of 8.53 percent. Second, I assume that the profit margin and dividend payout ratio both remain constant, at 36.15 and 25.00 percent, respectively, and that sales growth declines to a long-term estimate of 6.24 percent.



Continuing with the valuation example, the upper value of $13.31 suggests it is likely that a significant proportion of Microsoft equity value is comprised of something other than the present value of expected future dividends. This is even more apparent when we consider the assumptions required in order for the discounted cash flow valuation to reach the share price of $25.31. For example, we could make an adjustment to the long-term growth rate in sales, and maintain the long-term profit margin at 36.15 percent. In this case, to reach a valuation of $25.31, we require long-term sales growth of 12.98 percent. At a reinvestment rate of 75 percent, this is consistent with an assumed return on equity on new investments of 17.31 percent, nearly 6 percent above the required return to equityholders. The valuations listed above and their underlying assumptions are summarised in the exhibit below.

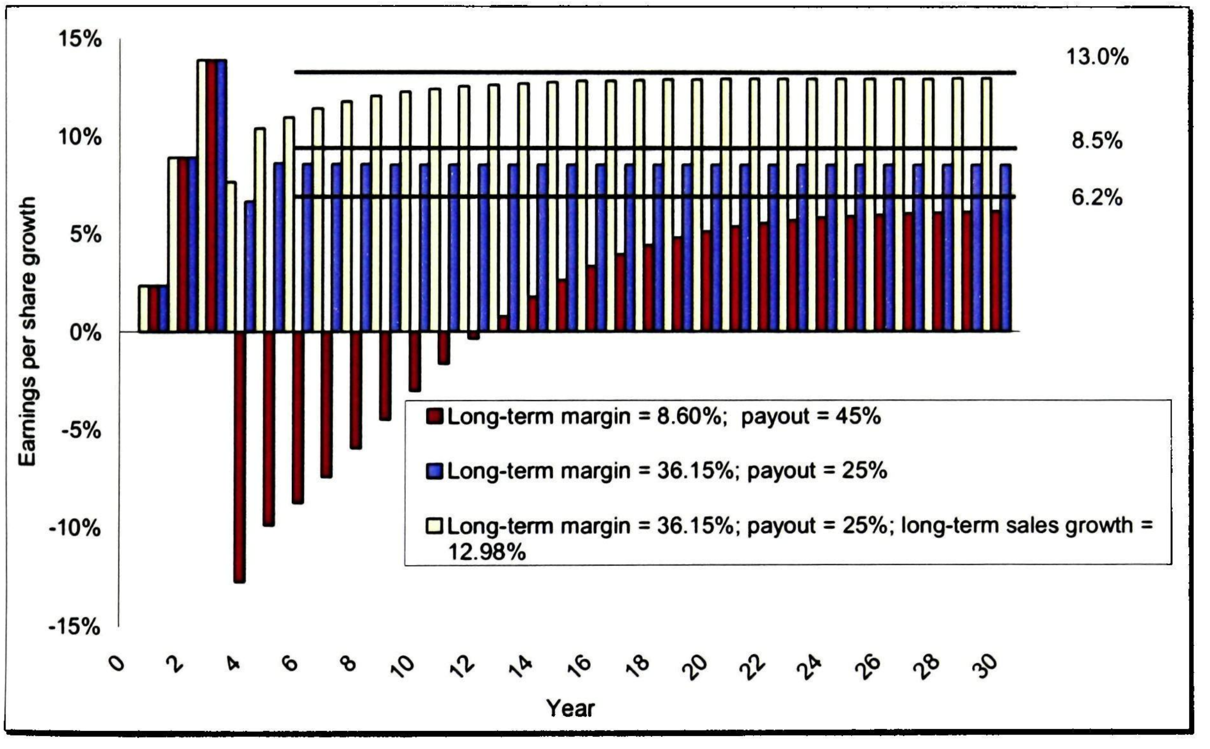
Exhibit 2.7
***DCF* valuations of Microsoft and underlying assumptions**

Valuation	Implied price-earnings ratio	Dividend payout ratio	Initial profit margin	Long-term profit margin	Initial growth	Long-term sales and EPS growth	ROE consistent with long-term EPS growth
$6.91	5.4	45.13%	36.15%	8.60%	8.66%	6.24%	11.38%
13.31	10.3	25.00	36.15	36.15	8.66	8.53	11.38
25.31	19.6	25.00	36.15	36.15	8.66	12.98	17.31

The EPS growth required to sustain a *DCF* valuation equal to the current share price is illustrated in Figure 2.2. Compared to the explicit forecast period (years 1 to 3) long-term EPS growth of 12.98 percent does not appear all that unreasonable. However, recall that this growth is required to be sustained in perpetuity, and requires significant abnormal return on equity investments made by Microsoft (that is, 6 percent above the cost of equity). While Microsoft is one firm whose historical investments have earned returns which greatly exceeded required returns, the issue is whether the market is pricing Microsoft under the assumption that *expected* returns are maintained at this high level; or whether expected returns are somewhat lower, but there is some value in the option to alter investment policy depending on the state of the market.

Figure 2.2
EPS growth underlying the illustrative *DCF* valuation of Microsoft, calibrated to a value of $25.31

Figure 2.2 presents the expected growth in earnings per share for Microsoft under three sets of assumptions. The first two sets of assumptions are the same as those underlying Figure 2.1. The third set of assumptions are consistent with a *DCF* valuation of $25.31. First, over forecast years 4 to 30, I assume that the profit margin declines from an initial value of 36.15 percent to a long-term expected value of 8.60 percent, and the dividend payout ratio remains constant at 45.13 percent. I assume that sales growth declines from an initial value of 8.66 percent to a long-term estimate of 8.53 percent. Second, I assume that the profit margin and dividend payout ratio both remain constant, at 36.15 and 25.00 percent, respectively, and that sales growth declines to a long-term estimate of 6.24 percent. Third, I maintain the same profit margin and dividend payout ratio as in assumption set 2, but assume that sales growth rises to a long-term estimate of 12.98 percent.



The Microsoft example illustrates a further important point regarding the parameter estimation techniques used in this large sample study, and the interpretation of the results. I do not contend that the parameter estimation techniques described in this paper are appropriate for the valuation of an individual stock. For example, the equity valuation conducted prior to an IPO or a proposed takeover should rely on company-specific estimates of the initial and long-term margins, dividend policy and the cost of equity capital. In the Microsoft case, the expected long-term margin is likely to fall somewhere in the range of 8.60 – 36.15 percent assumed above. It is equally possible that the expected long-term return on equity may exceed the cost of equity capital, if the investor has reason to believe that barriers to entry are unusually high in the industry in question.

However, the estimation techniques used in the analysis are appropriate for determining the usefulness of the proposed models for portfolio formation. The models will be useful for portfolio formation if, *on average*, market prices adjust to the intrinsic value estimates generated by the models. If, in reality this is the case, it is reasonable to expect that portfolios formed along intrinsic value lines will achieve outperformance.

In sum, the Microsoft example is illustrative of the empirical evidence that market prices exceed discounted cash flow valuations. At a forecast price-earnings ratio of 19.6 times, its discounted cash flow valuation only reaches the share price under the assumptions that the firm can sustain high margins on its current and future investments, and that the returns on those new investments are substantially above the cost of equity capital. In Sub-section 3.2, I describe the *Decision-tree* valuation model, which encompasses the value of dynamic reinvestment, and illustrate this model with another Microsoft valuation. Using a *Decision-tree* valuation model, the share price of $25.31 can be justified under more realistic assumptions that the *ROE* on reinvested earnings is 11-14 percent.

3.2 *Decision-tree* valuation

The *Decision-tree* valuation model is a modified version of that proposed by Schwartz and Moon (2001), which extends on the original model presented in Schwartz and Moon (2000). Their model incorporates six state variables in the valuation. Three of these are stochastic (revenue, revenue growth and variable costs) while three are path-dependent and deterministic (cash, tax losses carried forward, and property, plant and equipment). Underlying their model is the mean reversion of financial statement items and changes in those items as the firm matures and eventually achieves a steady state. Specifically, the model assumes that revenue growth, the volatility of that revenue growth and variable costs as a percentage of revenue revert to normal levels over a period of time.

In their paper, the model is derived in continuous-time, but converted to a discrete-time version in order to illustrate its use with valuations of Amazon.com and Ebay. Applying the model also required additional assumptions relating to capital expenditure, fixed costs and an EBIT multiple to estimate the terminal value.

In my analysis, I compute a *Decision-tree* valuation of each stock, according to the model summarised in Exhibit 2.9. The valuation is the mean of 1000 discounted cash flow valuations, where revenue growth is subject to uncertainty over its expected path, as well as deviations from this expected path. Discounting is performed using the same constant cost of equity capital as incorporated in the *DCF* valuation. Hence, these are not real options valuations, in which the value of cash flows derived from risk-neutral revenue growth are discounted using the risk-free rate.

The decision to perform *Decision-tree* valuations, as opposed to real options valuations, was made to minimise the standard error associated with estimating theoretical equity values. Essentially, the *Decision-tree* valuation model assumes that the systematic risk of equity is independent of the volatility of revenue growth. A real options valuation model assumes that the systematic risk of equity is positively correlated with the volatility of revenue growth. So estimating risk-neutral cash flows requires simulated cash flows to be discounted by a risk-adjustment factor (λ) related to the volatility of revenue growth. Schwartz and Moon (2000, 2001) provide a procedure for estimating this parameter. But this procedure requires an explicit assumption relating to the relationship between changes in equity value and changes in revenue, which is even more problematic. Further, while Schwartz and Moon (2000, 2001) model the relationship between equity value, revenue growth and the risk-adjustment factor, their examples rely on an arbitrary estimate for this factor. Hence, they have made the same trade-off between increasing the standard error of valuations and estimating additional parameters using market data. This point is further explored in Sub-section 3.3.2.

Each simulated *Decision-tree* valuation incorporates uncertainty over expected revenue growth, uncertainty over unexpected revenue growth, and uncertainty over the net profit margin. The model for the *Decision-tree* valuation is illustrated in Exhibits 6 and 7 below. The equations presented in Exhibit 2.9 are derived in Sub-section 3.2.1 and the techniques used to estimate the parameters in addition to the *DCF* model, are detailed in Sub-section 3.4.

Exhibit 2.8
Flowchart illustrating the *Decision-tree* valuation model

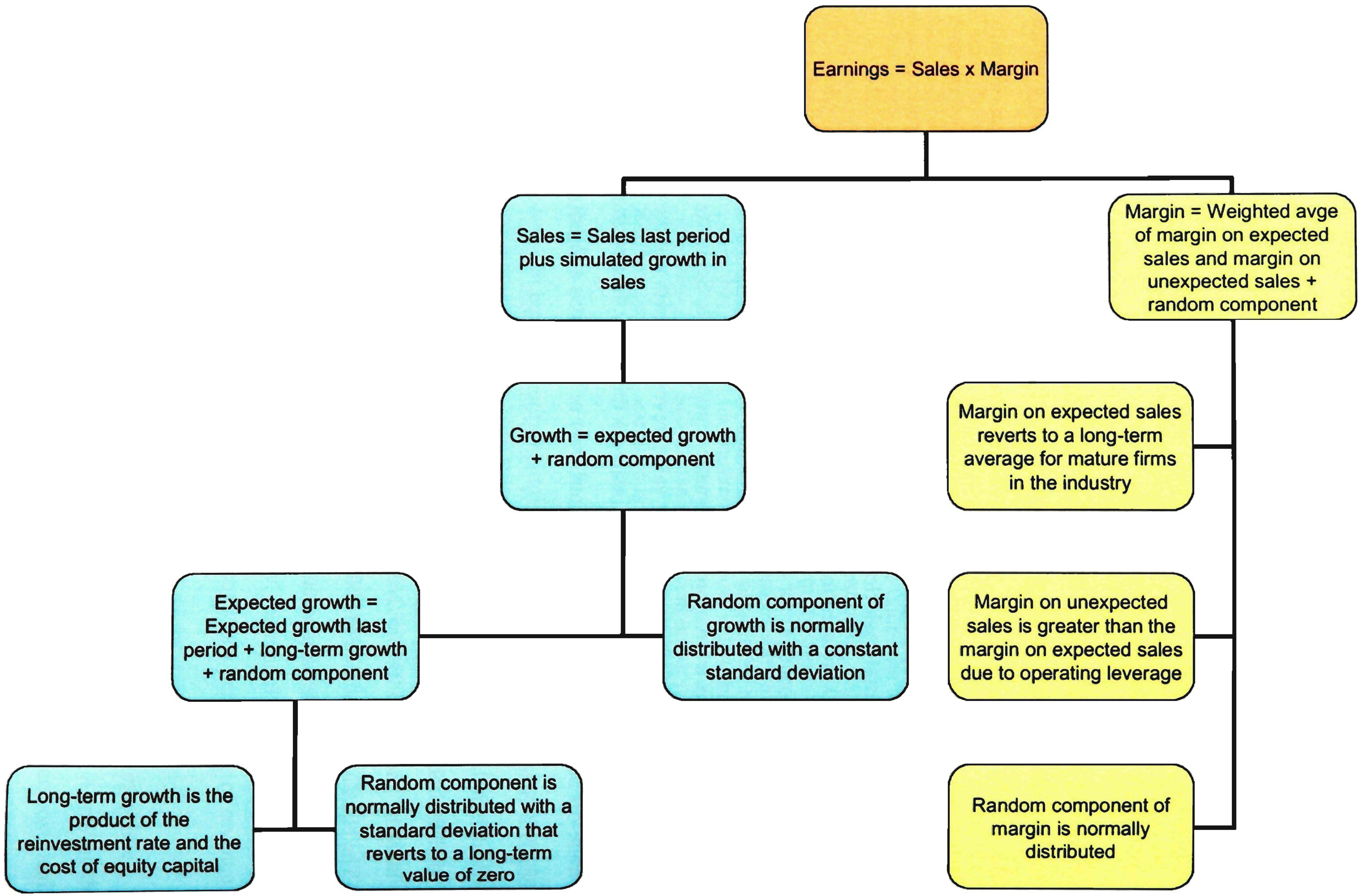


Exhibit 2.9
***Decision-tree* valuation summary**

Decision-tree valuation

The *DCF* valuation is the present value of expected future dividends, where dividends are the product of sales per share (*S*), profit margin (*m*) and the dividend payout ratio (*p*), but cannot be negative. The three terms of the model correspond to the explicit forecast period (*n* years), the remainder of the competitive advantage period (*T* years), and the terminal growth period (after year $n + T$). The *Decision-tree* valuation is the mean estimate of *k* *DCF* valuations, where k=1000 in the study.

$$DCF^j = \sum_{i=1}^{n} \frac{Max(p_i m_i S_i, 0)}{e^{r_e i}} + \sum_{i=n+1}^{n+T-1} \frac{Max\left(pm_i S_n e^{\sum_{i=n+1}^{n+T-1} g_i}, 0 \right)}{e^{r_e i}} + \frac{\overline{m} S_n e^{\sum_{i=n+1}^{n+T} g_i}}{r_e e^{r_e(n+T-1)}}$$

$$DTV = \sum_{j=1}^{k} \frac{DCF^j}{k}$$

Revenue growth

Revenue growth (g) is the sum of expected growth (μ) and unexpected growth ($\sigma\varepsilon_2$). The standard deviation of unexpected growth declines asymptotically to a long-term estimate $(\overline{\sigma})$.

$$g_i = \mu_i + \sigma_i \varepsilon_2$$

$$\sigma_i = e^{-\kappa}\sigma_{i-1} + \left(1 - e^{-\kappa}\right)\overline{\sigma}$$

Expected revenue growth is also uncertain. Its mean estimate and standard deviation both decline asymptotically to long-term estimates ($\overline{\mu}$ and 0, respectively).

$$\mu_i = e^{-\kappa}\mu_{i-1} + \left(1 - e^{-\kappa}\right)\overline{\mu} + \sqrt{\frac{1 - e^{-2\kappa}}{2\kappa}}\eta_i \varepsilon_1$$

$$\eta_i = e^{-\kappa}\eta_{i-1}$$

Profit margin

Profit margin (m) is a weighted average of the margin on expected sales (m^f) and the margin on unexpected sales ($\hat{m}$), plus a random component. The forecast margin declines asymptotically to its long-term estimate ($\overline{m}$) and the random component is normally distributed with mean zero and standard deviation δ.

$$m_i = m_i^f\left(e^{\mu_i - g_i}\right) + \hat{m}\left(1 - e^{\mu_i - g_i}\right) + \delta\varepsilon_3$$

$$m_i^f = e^{-\kappa} m_{i-1} + \left(1 - e^{-\kappa}\right)\overline{m}$$

$$= e^{-\kappa(i-n)}\left(m_n - \overline{m}\right) + \overline{m}$$

Variable definitions

DCF^j = the discounted cash flow valuation of equity under simulation j of k simulations;
DTV = the *Decision-tree* value of equity;
E_i = estimated earnings in year i;
S_n = estimated sales per share in year n;
p_i, p = dividend payout ratio in year i; and dividend payout ratio from year n + 1 onwards;
$\mu_i, \overline{\mu}$ = expected revenue growth in period i and its long-term sustainable level;
$\sqrt{\frac{1 - e^{-2\kappa}}{2\kappa}}\eta_i$ = standard deviation of expected revenue growth in period i;
$\sigma_i, \overline{\sigma}$ = standard deviation of revenue growth in period i and long-term sustainable level;
g_i, g_n, $\overline{g}$ = simulated sales growth in period i; continuously-compounded sales growth in year n (initial growth); and long-term sustainable growth rate in sales.
m_i, m_i^f, $\overline{m}$, $\hat{m}$ = simulated net profit margin in period i; forecast net profit margin in period i, assuming reversion to the long-term margin; long-term net profit margin; and net profit margin on unexpected sales growth;
δ = standard deviation of the random component of profit margin, due to uncertainty over costs;
ε_1, ε_2, ε_3 = standard normal variates.
r_e = continuously-compounded cost of equity capital
κ = speed of adjustment parameter for sales growth and profit margin.

3.2.1 Model derivation

In this section, I derive the equations presented in Exhibit 2.9. The model derivation is split into the components relating to simulated sales growth and net profit margin.

Estimation of sales growth

In the *DCF* model, revenue growth was deterministic, and reverted to a long-term sustainable level over *T* years, from the end of the explicit forecast period (years 1 to *n*) to the start of the sustainable growth period (year $n + T$). In the *Decision-tree* model, revenue growth in each year (g_i) is the sum of expected revenue growth (μ_i) and an unexpected component ($\sigma_i \varepsilon_1$). In addition, there is uncertainty over *expected* revenue growth in each year. The derivation of revenue growth is as follows.

Incorporating the continuous-time modelling of Schwartz and Moon (2000) I assume innovations in revenue to be normally distributed with mean $\mu(t)$ and standard deviation $\sigma(t)$, which are themselves stochastic variables. This can be expressed as:

$$\frac{dR(t)}{R(t)} = \mu(t)dt + \sigma(t)dz_1 \qquad (2.21)$$

where:

$R(t)$ = revenue at time t;

$\mu(t)$ = expected revenue growth at time t;

$\sigma(t)$ = standard deviation of revenue growth at time t; and

dz_1 = a normally distributed random variable with mean zero and standard deviation one.

I assume that expected revenue growth, or drift, (μ) is determined by mean reversion and a random element. It mean reverts to a constant rate $\bar{\mu}$ at rate κ, but randomness is introduced by the normally distributed random variable $\eta(t)$, which itself reverts to a long-term rate of $\bar{\eta}$. These assumptions are incorporated into the equations presented below.

$$d\mu(t) = \kappa[\bar{\mu} - \mu(t)]dt + \eta(t)dz_2 \qquad (2.22)$$

$$d\sigma(t) = \kappa[\bar{\sigma} - \sigma(t)]dt \qquad (2.23)$$

$$d\eta(t) = \kappa[\bar{\eta} - \eta(t)]dt \qquad (2.24)$$

where:

$\bar{\mu}$ = long-term expected revenue growth;

$\bar{\sigma}$ = long-term standard deviation of revenue growth;

$\eta(t)$ = the standard deviation of expected revenue growth in period t;

$\bar{\eta}$ = long-term standard deviation of expected revenue growth;

κ = the speed of adjustment parameter (the same as in the *DCF* model); and

dz_2 = a normally distributed random variable with mean zero and standard deviation one.

The discrete-time version of the above processes is presented below, assuming the increment of time (Δt) equals 1 year. It is consistent with Schwartz and Moon (2000, 2001), with two exceptions. First, risk-neutral earnings growth is not computed, in order to reduce the number of parameters requiring estimation. As mentioned above, I perform sensitivity analysis on the results after estimating risk-neutral earnings growth. Second, Schwartz and Moon allow for correlation between dz_1 and dz_2, where I assume that the correlation between these variables is zero. Again, this assumption is made to simplify the model for application to a large sample of stocks. σ_n and η_n, represent initial values for these volatility parameters at the end of the explicit forecast period. Variables ε_1 and ε_2 are standard normal variates. Note that I represent years with the sub-script i, for consistency with the earlier modelling.

$$S_i = S_{i-1}e^{g_i} \tag{2.25}$$

$$\mu_i = e^{-\kappa}\mu_{i-1} + \left(1-e^{-\kappa}\right)\bar{\mu} + \sqrt{\frac{\left(1-e^{-2\kappa}\right)}{2\kappa}}\eta_i\varepsilon_2 \tag{2.26}$$

where:

$$g_i = \mu_i + \sigma_i\varepsilon_1 \tag{2.27}$$

$$\eta_i = e^{-\kappa}\eta_{i-1} + \left(1-e^{-\kappa}\right)\bar{\eta} \tag{2.28}$$

$$\sigma_i = e^{-\kappa}\sigma_{i-1} + \left(1-e^{-\kappa}\right)\bar{\sigma} \tag{2.29}$$

I than make the further assumption that the volatility of expected revenue growth declines to a long-term estimate of zero, implying that:

$$\eta_i = e^{-\kappa}\eta_{i-1} \tag{2.30}$$

This assumption, which was also made by Schwartz and Moon (2000) can be justified on economic grounds. Recall that this is the volatility of expected revenue growth, not the volatility of realised revenue growth, and the model is being used to value equity investments based on an information set available today. The assumption that $\bar{\eta} = 0$ implies that uncertainty over the drift term diminishes over time. This is what we would expect of mature industries, even if there is volatility in year-to-year revenue growth.

Estimation of the net profit margin

In the *DCF* model, the forecast net profit margin in each year was deterministic, and reverted to a long-term expected value of $\overline{m}$. In the *Decision-tree* valuation model, the profit margin in a given year (m_i) is influenced by two other factors: (1) the difference between expected and unexpected revenue; and (2) uncertainty over costs. The profit margin on the unexpected component of revenue growth is likely to be greater than the margin on the expected component. This occurs because there are likely to be fewer costs associated with earning the unexpected revenue. For example, if demand for motor vehicles was 10 percent above expectations, there is likely to be an increase in wages costs (especially overtime) but the profit margin would likely still increase, because other costs like depreciation and managers' salaries are fixed. For software firms, this impact is likely to be even greater, given that there is likely to be little increase in costs in response to unexpected demand for software. This can be modelled as follows.

Say we disaggregate sales into an expected component and an unexpected component as follows:

$$S_i = S_{i-1}e^{g_i} = S_{i-1}e^{\mu_i} + S_{i-1}\left(e^{g_i} - e^{\mu_i}\right) \tag{2.31}$$

The earnings generated by each of these sales components is the product of a profit margin and sales. If we label the margin on *expected* sales as m_i^f and the margin on *unexpected* sales as $\hat{m}$, earnings can be expressed as follows:

$$E_i = m_i^f S_{i-1}e^{\mu_i} + \hat{m}S_{i-1}\left(e^{g_i} - e^{\mu_i}\right) \tag{2.32}$$

Dividing both sides of the equation by sales in year *i*, we have an expression for profit margin which is a weighted sum of the margin on expected and unexpected sales:

$$m_i = \frac{m_i^f S_{i-1}e^{\mu_i}}{S_i} + \frac{\hat{m}S_{i-1}\left(e^{g_i} - e^{\mu_i}\right)}{S_i} \tag{2.33}$$

If me make the further substitution that $S_i = S_{i-1}e^{g_i}$ we have the following equation:

$$\begin{aligned} m_i &= \frac{m_i^f S_{i-1}e^{\mu_i}}{S_{i-1}e^{g_i}} + \frac{\hat{m}S_{i-1}\left(e^{g_i} - e^{\mu_i}\right)}{S_{i-1}e^{g_i}} \\ &= m_i^f e^{\mu_i - g_i} + \hat{m}\left(1 - e^{\mu_i - g_i}\right) \end{aligned} \tag{2.34}$$

This equation shows that the profit margin is a weighted average of the profit margin on expected earnings and the profit margin on unexpected earnings, where the weights are determined by the difference between expected and realised revenue growth.

This is the profit margin we would observe in the absence of any cost variance. In other words, if sales were above expectations, but the increased costs associated with those sales were the same as forecast, we would observe the weighted margin from this equation. If we then assume there is a random component to the realised margin, with mean zero and standard deviation of δ, we have the following equation for profit margin:

$$m_i = m_i^f e^{\mu_i - g_i} + \hat{m}\left(1 - e^{\mu_i - g_i}\right) + \delta\varepsilon_3 \tag{2.35}$$

where:

$$m_i^f = e^{-\kappa(i-n)}\left(m_n - \overline{m}\right) + \overline{m} \tag{2.36}$$

(assuming that, for consistency with the *DCF* valuation model, the margin on expected sales asymptotically reverts to a long-term expected value, $\overline{m}$).

3.2.2 Example: Decision-tree valuation of Microsoft

As was the case for the *DCF* valuation model, I illustrate the *Decision-tree* valuation model with a valuation for Microsoft. Recall the set of assumptions used in the *DCF* valuation of Microsoft – cost of equity (r_e) = 11.38 percent, initial profit margin (m_n) = 36.15 percent, long-term profit margin ($\overline{m}$) = 8.60 percent, dividend payout ratio (p) = 45.13 percent, initial sales growth (g_n) = 8.66 percent, long-term sales growth $\left(\overline{g}\right)$ = 6.24 percent, explicit forecast period (n) = 3 years, and competitive advantage period (n + T) = 30 years. These assumptions were consistent with a *DCF* valuation of \$6.91. Under the assumption that the profit margin remains constant at 36.15 percent, the valuation increased to \$13.31 percent, and only reached the share price of \$25.31 under the assumption that long-term sales growth is 12.98 percent.

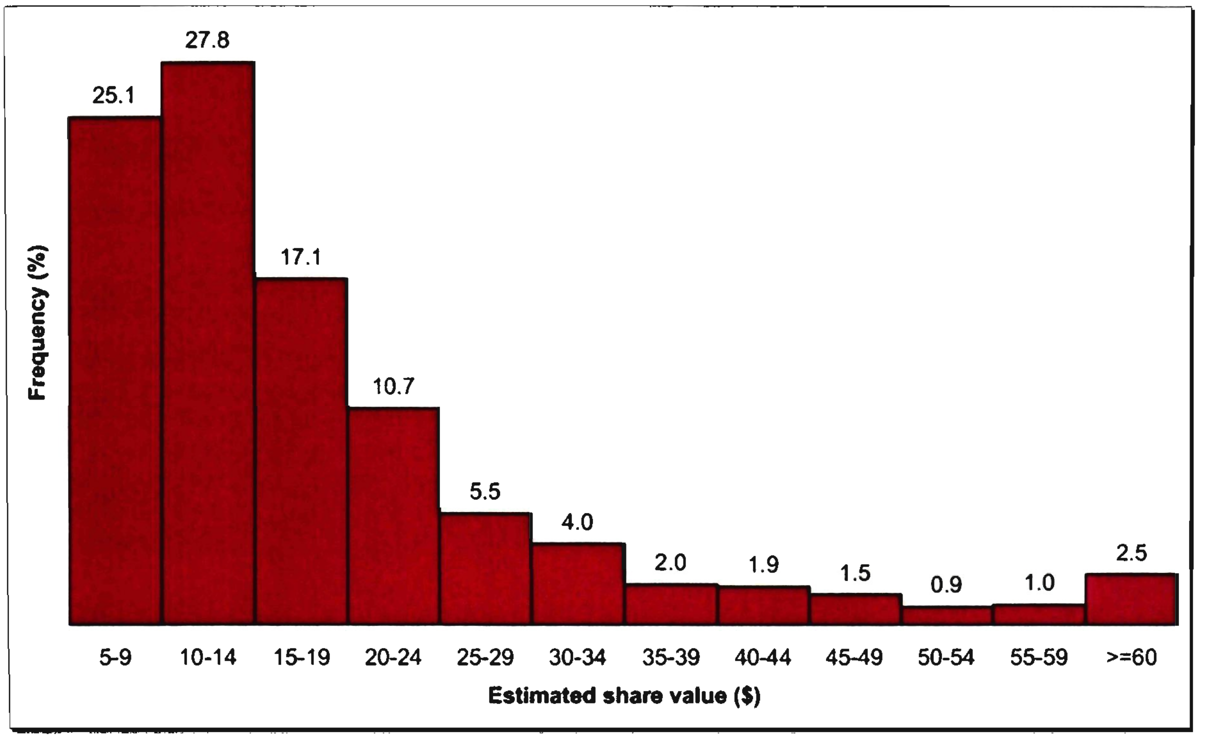
Now incorporate some assumptions relating to the uncertainty over revenue growth and margins. These are broadly comparable to the assumptions used for Technology stocks in the full sample. First, assume that the volatility of expected sales growth (σ_n) is 20 percent and is expected to remain at this level for the purposes of the example, so that $\overline{\sigma}$ = 20 percent. Second, assume that the initial volatility of the unexpected component of sales growth (η_n) is equal to 0.10, which is expected to revert to zero in the long-term. Third, assume that the margin on unexpected revenue growth ($\hat{m}$) is 1.5 times the long-term margin, so is equal to 12.90 percent in the low margin case, and 54.23 percent in the high-margin case. Finally, assume that the standard deviation of the uncertain component of margin (that is, the volatility in margin due to uncertainty over costs; δ) is 50 percent of the long-term margin, so is equal to 4.30 percent in the low-margin case and 18.08 percent in the high-margin case.

Under the original set of assumptions – that the expected long-term profit margin is 8.60 percent and the dividend payout ratio is 45.13 percent – the valuation rises 16 percent to $8.01. This valuation is the mean estimate of value from 1000 simulated paths of sales, earnings and dividend growth. This is consistent with embedded options comprising 14 percent of share value, where the *DCF* value is $6.91 and embedded options adding another $1.10 of value. Under the second set of assumptions – that the expected long-term profit margin remains at 36.15 percent and the dividend payout ratio is 25 percent – share value rises to $18.68, a 40 percent increase from the *DCF* value of $13.31. In this instance, embedded options comprise 29 percent of share value.

The impact of the volatility assumption on estimated share price is illustrated in Figure 2.3, which shows the distribution of estimated share values under the second set of assumptions, where margin is maintained at 36.15 percent and the dividend payout ratio is 25 percent. The figure shows the skewed distribution of estimated share value, which is a function of the asymmetric impact on earnings per share of embedded options. In the situations where there is an unexpected increase in earnings growth, the firm re-invests additional funds in high-growth projects. For example, the Microsoft valuation at the 95th percentile of the distribution is $46.67, which is consistent with a price-earnings ratio of 36.2. This is largely the result of simulated sales growth of 54.9 percent in forecast year 17, compared to an original estimate of 8.5 percent for this example in that year. Combined with a simulated margin of 66.2 percent, this resulted in earnings per share of $29.30, which was over 5 times the *DCF* forecast of $5.27 for that year.

Figure 2.3
Distribution of the simulated *Decision-tree* valuations for the Microsoft illustration

Figure 2.3 presents the distribution of 1000 simulated Decision-tree valuations for Microsoft under the following assumptions, which are consistent with a mean valuation estimate of $19.11. I assume that the dividend payout ratio remains constant at 25.00 percent and that expected sales growth declines to a long-term estimate of 8.53 percent. In addition, I assume that expected sales growth in each period is normally distributed with standard deviation η, which declines from an initial value in year 3 of 10 percent to a long-term estimate of zero by year 30; and that unexpected sales growth in each year is normally distributed with standard deviation σ, which remains constant at 20 percent. In relation to the profit margin, I assume that the expected profit margin remains constant at 36.15 percent, the margin on unexpected sales growth (positive or negative) is 54.23 percent (1.5 times the expected profit margin) and that the random component of the profit margin is normally distributed with mean zero and standard deviation of 18.08 percent (half the expected profit margin).



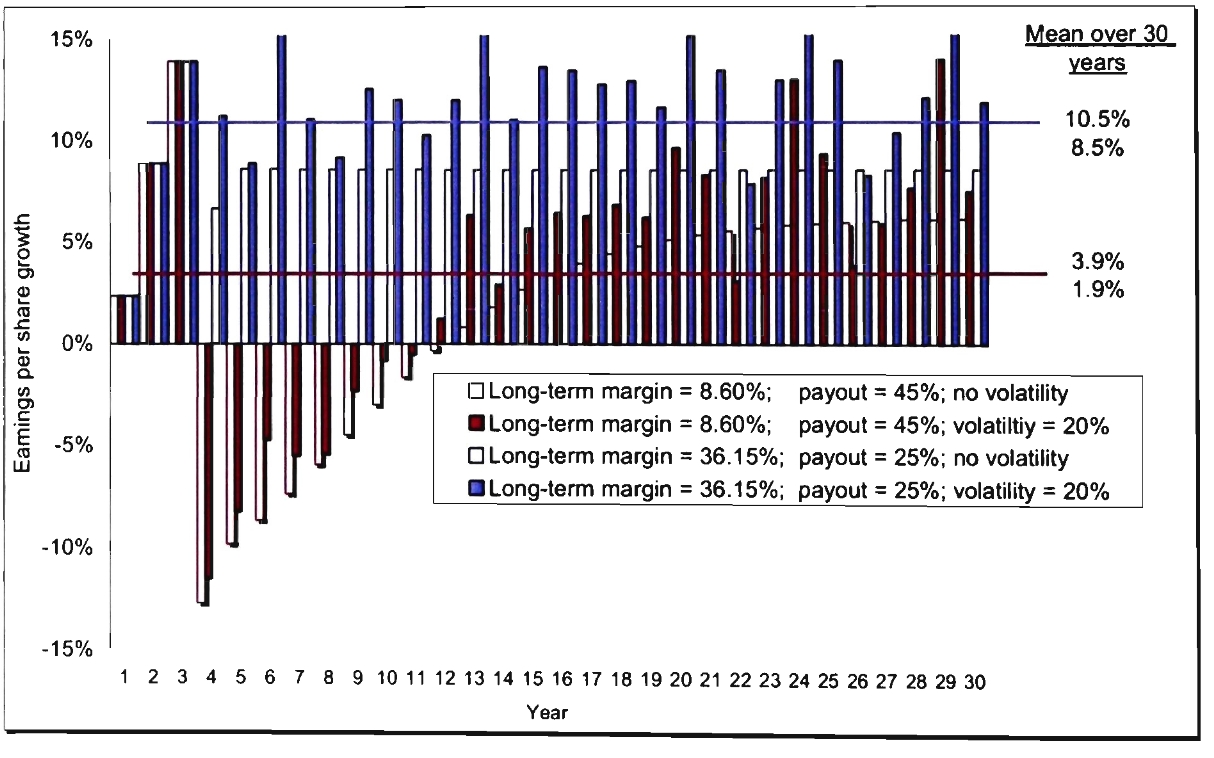
An important assumption of this model is that a portion of these unexpected earnings are reinvested back in the firm, which is consistent with the firm exercising a growth option in response to feedback (that is, high growth) that its current business segments are worthy of additional investment. In this example, assuming a reinvestment rate of 75 percent means that $18.02 per share was reinvested in excess of what was expected. And since the firm is in a state where these investments are expected to be positive-NPV projects, this is a rational exercise of an option.

The contrasting state in which the firm exercises an option to abandon a business segment, or at least scale down its operations, is the case where it receives feedback that its projects are not successful (that is, a low growth state). The 5^{th} percentile of the distribution above is a share value of $6.57, which is largely the result of a 68 percent fall in earnings per share in year 21, from $2.31 to $0.74. This resulted in earnings per share being 90 percent below expectations. This also means that reinvested earnings is $5.00 per share lower than expected, which is a rational response to feedback that the current investment portfolio is underperforming.

These arguments are further illustrated in Figure 2.4, which displays the growth in expected EPS over 30 years in four cases. These are the four combinations of the low- and high-margin assumptions, and including and excluding volatility of sales growth and margins. The clear bars present the same EPS growth data that appears in Figure 2.1, while the shaded bars present the mean annual growth over 30 years in average EPS from 1000 simulated sales and EPS paths. The horizontal lines illustrate the average growth in EPS in the four cases. In the low-margin cases, mean growth in average EPS increases from 1.9 percent to 3.9 percent. In the high-margin case, growth in average EPS increases from 8.5 percent to 10.5 percent. These differences result from the greater dollar amount of reinvestment in high growth states, and a lower dollar amount of reinvestment in low growth states.

Figure 2.4
Growth in average EPS underlying illustrative *DCF* and *Decision-tree* valuations of Microsoft

Figure 2.4 presents the growth in average earnings per share for Microsoft under four sets of assumptions. Two sets of assumptions, underlying the data presented in the clear bars, are the same as those underlying Figure 2.1: (1) profit margin is expected to decline from 36.15 percent to 8.60 percent and dividend payout ratio is 45.13 percent; and (2) profit margin remains constant at 36.15 percent and dividend payout ratio is 25 percent. The other two sets of assumptions, underlying the data presented in the shaded bars, incorporate the assumptions that expected growth in EPS is normally distributed with standard deviation η, which declines from an initial value in year 3 of 10 percent to a long-term estimate of zero by year 30; and that unexpected sales growth in each year is normally distributed with standard deviation σ, which remains constant at 20 percent.



Finally, it is worthwhile investigating the set of assumptions consistent with a valuation of \$25.31 for Microsoft. First, say we hold the margin constant at 36.15 percent assume that expected sales growth reverts to 8.53 percent over 30 years, consistent with expected equity returns on reinvested earnings reverting to a normal level over time. In this case, volatility of sales growth equal to 27 percent is required to reach this value. This is not an unreasonable estimate, given the descriptive statistics on volatility presented in Table 2.1, and discussed later. Alternatively, holding the volatility of sales growth constant at 20 percent, the share price of $25.31 can be justified with the assumption that long-term sales growth is 10.5 percent. This is consistent with new investment return on equity remaining at 14.0 percent, still 2.6 percent above the cost of capital, but a more reasonable assumption than the 17.3 percent required under the *DCF* valuation.

The following exhibit summarises the illustrative valuations for Microsoft, with highlighted rows indicating the assumption sets which are consistent with valuations equal to the current share price of $25.31. This data provides an indication of the magnitude of assumptions required to justify this market price. For instance, the share price is consistent with the following sets of assumptions:

- long-term ROE on new investments is equal to 14.0 percent, and 32 percent of equity value comprised of the value of embedded options, proxied by the volatility assumption of 20 percent (row 3);
- long-term ROE on new investments is equal to 17.3 percent and no value in the market price for embedded options (row 4);
- long-term ROE on new investments is equal to 11.4 percent (the cost of equity capital), and 47 percent of equity value comprised of the value of embedded options, proxied by the volatility assumption of 27 percent (row 6).

Exhibit 2.10
Microsoft valuations under alternative assumptions and valuation models

	DCF valuation		*Decision-tree* val		Vol-	Div	Margin		Sales growth		LT
Row	Val	P/E	Val	P/E	atility	payout	Initial	LT	Initial	LT	ROE
1	$6.91	5.4	$8.01	6.2	20%	45.1%	36.2%	8.6%	8.66%	6.2%	11.4%
2	13.31	10.3	18.68	14.5	20	25.0	36.2	36.2	8.66	8.5	11.4
3	17.32	13.4	25.31	19.6	20	25.0	36.2	36.2	8.66	10.5	14.0
4	25.31	19.6	38.87	30.1	20	25.0	36.2	36.2	8.66	13.0	17.3
5	$6.91	5.4	9.34	7.2	27	45.1	36.2	8.6	8.66	6.2	11.4
6	13.31	10.3	25.31	19.6	27	25.0	36.2	36.2	8.66	8.5	11.4
7	17.32	13.4	35.65	27.6	27	25.0	36.2	36.2	8.66	10.5	14.0
8	25.31	19.6	56.75	44.0	27	25.0	36.2	36.2	8.66	13.0	17.3

In sum, the Microsoft example is illustrative of two important concepts underlying the *DCF* and *Decision-tree* valuation models. First, for a discounted cash flow valuation to justify a price-earnings ratio of 19.6 for a large, mature technology stock, requires an assumption that it can sustain investment returns well in excess of its cost of capital in perpetuity. The assumption of the *DCF* model examined here is that return on investment is expected to revert to a normal level over the competitive advantage period. Second, a price-earnings ratio of 19.6 can be justified at a more reasonable ROE assumption, if the volatility of sales growth is sufficiently high. The greater the volatility of growth, the greater the ability of management to alter investment decisions in response to signals of growth. This is operationalised in the model through the assumption that the dividend payout ratio is constant, meaning that there is a direct relationship between the magnitude of reinvestment and the growth signal.

3.3 Comparison to the Schwartz and Moon (2000, 2001) models

It is useful to compare the *DCF* and *Decisions-tree* valuation models with the real options valuation model presented in Schwartz and Moon (2000). Their model also involves the simulation of expected earnings for an assumed competitive advantage period. In the terminal state, value is estimated by multiplying earnings by an assumed multiple, and this value is discounted to present value terms. As with the *Decision-tree* model, their estimate of equity value is the mean estimate of simulated equity values. In Sub-section 3.3.1, I compare the assumptions underlying the estimate of earnings, which are deterministic for the *DCF* model and stochastic for the *Decision-tree* model. In Sub-section 3.3.2, I compare the way in which equity value is estimated. In making this comparison, my intention is two-fold. First, I argue that the assumptions relating to the derivation of earnings are appropriate for practitioners to implement, given firm-specific parameter estimates. Second, I argue that *Decision-tree* valuation can be justified, despite the use of a constant risk-adjusted discount rate, given the estimation error underlying the adjustment required to estimate risk-neutral cash flows.

The differences between the modelling used in this paper and those used by Schwartz and Moon (2000, 2001) are summarised in Exhibit 2.11. Note that I use terminology and symbols which are comparable to those used throughout this thesis, which are not necessarily the same as those used by Schwartz and Moon.

Note that these differences in modelling do not suggest that one model is "better" or "worse" than the other, they simply rely on a different set of assumptions, and any valuation model should be used only in cases where its assumptions are appropriate. Further, the primary contribution of Schwartz and Moon is the modelling of the real options valuation, using the stochastic processes upon which my paper relies. The intent of my research is to evaluate whether investors can earn abnormal returns from portfolios formed on the basis of these processes, in addition to the assumptions underlying the *DCF* model

Exhibit 2.11
Comparison with the model of Schwartz and Moon (2000, 2001)

Hall (2005)	Schwartz and Moon (2000, 2001)
Valuation Equity value for each simulation is the present value of future dividends, discounted as a constant risk-adjusted cost of equity capital. $DCF^j = \sum_{i=1}^{n} \frac{Max(p_i m_i S_i, 0)}{e^{r_e i}} + \sum_{i=n+1}^{n+T-1} \frac{Max\left(pm_i S_n e^{\sum_{i=n+1}^{n+T-1} g_i}, 0\right)}{e^{r_e i}} + \frac{\bar{m} S_n e^{\sum_{i=n+1}^{n+T} g_i}}{r_e e^{r_e(n+T-1)}}$	**Valuation** Equity value for each simulation is the present value of the sum of EBITDA capitalised at an arbitrary multiple (M) plus the cash balance at the end of the competitive advantage period. These values are derived under the assumption of risk-neutrality and discounted at the risk-free rate. The model assumes 100 percent reinvestment, but retained earnings earn their cost of capital (the risk-free rate) $V = E_Q\{X_{n+T} + M \times [R_{n+T}(1-\gamma_{n+T}) - F]\}$ where *X* refers to the cash balance, *M* is the *EBITDA* multiple, γ is variable costs as a percentage of sales and *F* is fixed costs, and E_Q refers to an expectation under risk-neutrality.
Revenue growth Revenue growth is expressed in nominal terms as the sum of a drift term and a random component. Its expected value reverts to a long-term mean estimate and is normally distributed. The random component of revenue growth is also normally distributed. $g_i = \mu_i + \sigma_i \varepsilon_2$ $\sigma_i = e^{-\kappa}\sigma_{i-1} + (1-e^{-\kappa})\bar{\sigma}$ $\mu_i = e^{-\kappa}\mu_{i-1} + (1-e^{-\kappa})\bar{\mu} + \sqrt{\frac{1-e^{-2\kappa}}{2\kappa}}\eta_i \varepsilon_1$ $\eta_i = e^{-\kappa}\eta_{i-1}$	**Revenue growth** Revenue growth is expressed in risk-neutral terms. Other assumptions are comparable. $g_i = \mu_i - \lambda_i \sigma_i - \frac{\sigma_i^2}{2} + \sigma_i \varepsilon_2$ $\sigma_i = e^{-\kappa}\sigma_{i-1} + (1-e^{-\kappa})\bar{\sigma}$ $\mu_i = e^{-\kappa}\mu_{i-1} + (1-e^{-\kappa})\bar{\mu} + \sqrt{\frac{1-e^{-2\kappa}}{2\kappa}}\eta_i \varepsilon_1$ $\eta_i = e^{-\kappa}\eta_{i-1}$
Earnings Earnings are the product of sales and margin, where margin is a weighted average of the margin on expected and unexpected sales, plus a random component. $E_i = S_i m_i$ $m_i = m_i^f(e^{\mu_i - g_i}) + \hat{m}(1 - e^{\mu_i - g_i}) + \delta\varepsilon_3$ $m_i^f = e^{-\kappa} m_{i-1} + (1-e^{-\kappa})\bar{m}$	**Earnings** Earnings are equal to the product of sales and (1 – variable costs as a percentage of sales) less fixed costs. Variable costs as a percentage of sales has a mean-reverting drift component and a random component. $E_i = S_i(1-\gamma_i) - F$ $\gamma_i = e^{-\kappa}\gamma_{i-1} + (1-e^{-\kappa})\bar{\gamma} + \sqrt{\frac{1-e^{-2\kappa}}{2\kappa}}\varphi\varepsilon_3$

Apart from the distinction between a real options and *Decision-tree* valuation model, which as discussed in the derivation of the *Decision-tree* model, I highlight the following differences in modelling.

Schwartz and Moon (2000) model the after-tax cash flow to an all-equity financed firm as follows. Note that the symbols and terminology used in their paper differ from those presented above, but the underlying equation is the same. The equation below refers to the case where capital expenditure equals depreciation. In their 2001 paper, Schwartz and Moon allow for this expansion case.

$$NPAT_i = [Sales_i(1-\gamma) - F][1-\tau] \tag{2.37}$$

Expressing the above equation on a per share basis we have:

$$E_i = [S_i(1-\gamma) - FPS][1-\tau] \tag{2.38}$$

where:

FPS_i = fixed costs per share in year *i*.

They model sales growth in the same way as that described above, such that:

$$S_i = S_{i-n}e^{g_i} \tag{2.39}$$

$$g_i = e^{-\kappa}g_{i-1} + \left(1-e^{-\kappa}\right)\overline{g} \tag{2.40}$$

Hence, the first difference in assumptions is the way sales growth is transferred to earnings growth. In the Schwartz and Moon model, fixed costs remain constant, so that earnings growth always exceeds sales growth, due to operating leverage. Economically, this model can only apply to growth firms, in which revenue growth is always high-quality. In my model, the relationship between earnings growth and revenue growth depends upon whether the profit margin is above or below the long-term sustainable margin.

The other differences in assumptions relate to the techniques used to estimate the models' parameters. In the Schwartz and Moon model, the proportion of variable costs and the amount of fixed costs are estimated according to analysts future projections, which is consistent with my use of EPS forecasts to estimate the initial margin. However, it is likely that EPS forecasts are more reliable than estimates of fixed and variable costs that can be obtained from analyst reports. This is due to the importance investors and companies place on the ability of companies to meet EPS forecasts, evidenced by the sharemarket reaction to positive and negative EPS surprise. Further, I use an economic justification for the use of long-run revenue growth as equal to the product of the reinvestment rate and the cost of equity capital, as discussed in Sub-section 3.1.2. Finally, in computing the terminal value, I rely on the assumption that reinvested earnings will earn just their cost of capital, such that the terminal value is the next year's expected earnings divided by the cost of capital. Schwartz and Moon rely upon an arbitrary estimate.

In sum, the differences between the assumptions underlying the *DCF* model presented above, and those relied upon by Schwartz and Moon, are as follows:

- In the sustainable growth period, fixed costs rise at a constant proportion of sales, implying that the profit margin is expected to remain constant. Schwartz and Moon assume that fixed costs remain constant in dollar terms, implying that profit margin continues to increase.
- In estimating the parameters of the *DCF* model, I rely on consensus EPS and Sales figures, while Schwartz and Moon suggest also estimating the proportion of fixed and variable costs.
- The long-term growth underlying the *DCF* model relies upon the economic justification that long-term earnings growth is the product of the reinvestment rate and the cost of equity capital, and that expected long-term revenue growth equals expected long-term earnings growth. Schwartz and Moon do not suggest an estimation procedure.
- The terminal value computation is expected earnings at the end of the competitive advantage divided by the cost of equity capital, consistent with the assumption that expected ROE will equal the cost of equity in this state. Schwartz and Moon do not suggest an appropriate estimation procedure for the multiple to be applied to terminal year earnings.

3.4 Parameter estimation

Implementing the model described in Section 3 requires estimation of a large number of parameters via methods that can be applied to a sample of firms over a number of years. These are not necessarily the techniques that would be applied for valuing a particular firm, say, in preparation for an IPO. In that case, firm-specific estimates of expected revenue growth, its expected volatility and so on, would be implemented. As discussed in several places above, in implementing any valuation model, the analyst makes a trade-off between the information gleaned from performing a more detailed analysis, and the uncertainty which is introduced via noisy parameter estimates. Hence, what I describe below are the techniques I have used to test the appropriateness of the *Decision-tree* valuation model for forming investment purposes. With a less noisy, firm-specific information set, investors should be expected to yield further benefits from explicitly accounting for the value of embedded options.

In this section, I outline the estimation procedure for the parameters required by the *DCF* and *Decision-tree* valuation models. Throughout, I have used an explicit forecast period of 3 years, implying that $n = 3$. I have made three assumptions regarding the competitive advantage period, which are that $n + T = 10$, 20 or 30 years.

3.4.1 Dividend payout ratio (p_i and p)

The dividend payout ratio used from the end of the explicit forecast period to the end of the *CAP* (the period of $T - 1$ years starting in year 4) is the average of the estimated dividend payout ratio for years 0 to 3. I also constrained the payout ratio in each year in the range of zero to one, to mitigate against the impact of special dividends or data errors, such as negative dividends, impacting on the results. Expressed as an equation this is:

$$p = \sum_{i=0}^{n} \frac{Max[Min(p_i,1),0]}{n+1} = \sum_{i=0}^{3} \frac{Max[Min(p_i,1),0]}{4} \qquad (2.41)$$

In forecast years 1 to 3, the dividend payout ratio is computed as the ratio of forecast dividends per share to forecast earnings per share, where the mean IBES consensus forecasts are available. In the instance where the dividend forecast is not available, but estimates of the book value per share were available, I estimate the dividend as the difference between the earnings per share in that year less the change in book value per share. There were cases where missing data meant that the dividend payout ratio could not be computed in a given year, but could be computed for at least one year from years 0 to 4. In these cases, I use p in place of p_i. I still constrain p_i to have a lower bound of zero, but remove the constraint that the maximum value equals one. In other words, dividends in an individual year can exceed earnings, but the maximum payout ratio used to estimate the longer-term payout ratio (p) cannot exceed 100 percent.

Hence, the computation of the dividend payout ratio in the explicit forecast period can be summarised according to the following equations:

$$p_i = Min\left(\frac{D_i}{E_i},0\right) \text{ or } p_i = Min\left(\frac{E_i - (BVE_i - BVE_{i-1})}{E_i},0\right) \qquad (2.42)$$

where:

BVE_i = book value of equity per share in year i.

3.4.2 Profit margin (m_i, m_n, $\overline{m}$, $\hat{m}$ and δ)

The initial profit margin (m_n) is the average of the estimated profit margin for years 0 to 3 (m_i where $i = 0$ to 3), where each year is constrained to have a maximum value of one. A value greater than one is consistent with earnings exceeding sales, which can only be the result of an unusual item affecting earnings or data errors. The profit margin in each individual year (m_i) is the ratio of sales per share to earnings per share. Expressed in equations, the initial profit margin and the profit margin in years 0 to 3 is:

$$m_n = \sum_{i=0}^{n} \frac{Max(m_i, 1)}{n+1} = \sum_{i=0}^{3} \frac{Max(m_i, 1)}{4} \qquad (2.43)$$

where:

$$m_i = \frac{E_i}{S_i}$$

The long-term profit margin ($\overline{m}$) is time-period and industry-specific. For each firm with at least five years of earnings history, I compute its average profit margin using the available historical data. The intent is to estimate an industry-wide profit margin for mature firms, which is the reasoning behind the five-year data requirement. The exception to the five-year requirement is for the 1987 and 1988 sub-samples. As data is only available from 1985 onwards, I estimate the long-term profit margin for those sub-samples using three- and four-year windows only. I also constrain the long-term margin estimate to be positive. Any other assumption would imply that mature firms in the industry are expected to be loss-making in the long-term. Expressed as an equation, the long-term profit margin is estimated using the historical earnings and sales for all firms in the same IBES industry sector as:

$$\overline{m} = Max\left(\frac{\sum_{j=1}^{n} \frac{\sum_{i=1}^{k} \frac{NPAT_{i,j}}{Sales_{i,j}}}{k}}{n}, 0 \right) \qquad (2.44)$$

where:

$NPAT_{i,j}$ = the net profit in year i for firm j;

$Sales_{i,j}$ = sales in year i for firm j;

k = the number of years of available data for firm i; and

n = the number of firms in the industry.

The *Decision-tree* valuation model also requires an assumption for the profit margin on unexpected sales ($\hat{m}$) and the volatility of profit margin due to cost variances *(δ)*. To estimate the margin on unexpected sales I performed the following four-step estimation procedure. First, I computed the change in earnings relative to the change in sales for each firm, year, according to the following equation:

$$Margin\ on\ sales\ growth_i = \frac{NPAT_i - NPAT_{i-1}}{Sales_i - Sales_{i-1}} \qquad (2.45)$$

This provides an estimate of the profit margin on the change in sales from the previous year, under the assumption that profit margin on base year sales was unchanged. Second, I excluded observations in which earnings and sales moved in opposite directions. In this case, the estimated margin on sales growth would be negative, which would lead to the assumption that firms would incur losses simply to generate higher sales. Third, I estimated the mean margin on sales growth for firms within the same IBES Sector in the same year. Finally, I capped this estimate at 0.5 on the basis that this is approximately two standard deviations above the typical initial margin. (A firm which can earn a margin on unexpected sales which is two standard deviations above the margin for the typical firm would have unusually high operating leverage).

For each firm-year, I use its industry sector average as the assumed margin on unexpected sales for all subsequent years. This ensures that the valuations are only performed using data that is available prior to portfolio formation.

The last parameter relating to margins that requires estimation is the random component *(δ)*. I assume this takes a value which is 0.5 times the firm's long-term margin estimate (which is time-period and industry-specific). Under the assumption that profit margin is normally distributed, this assumption implies that, in steady state, the probability of incurring a loss is about 2 percent. This is reasonable, considering that 7 percent of sample firms had negative earnings in the last actual reported year, and the sample is drawn from large firms. And the figure of 2 percent refers to losses incurred when actual sales are as forecast, not due to a sudden drop in revenue. In other words, this assumption appears reasonable, considering that there is a low probability that a large firm, with steady-state revenue growth, will incur losses purely because of a sudden rise in costs.

3.4.3 Sales per share (S_i and S_n) and growth in sales per share (g_i, g_n and $\bar{g}$)

Sales per share during the explicit forecast period and for the final year of historical data (S_i where i = 0 to 3) is simply the ratio of actual sales (S_0) or the IBES consensus sales forecast

(S_1 to S_3) divided by the actual or forecast shares on issue, provided by IBES. Growth in sales per share in individual years (g_i) is computed as the natural logarithm of the ratio of sales per share in the current and previous periods. Initial growth in sales per share (g_n) is the average of the estimated sales growth from years 0 to 3. Expressed in equations, we have:

$$S_i = \frac{Sales_i}{Shares_i} \tag{2.46}$$

$$g_i = \ln\left(\frac{S_i}{S_{i-1}}\right) \tag{2.47}$$

$$g_n = \sum_{i=0}^{n} \frac{g_i}{n+1} = \sum_{i=0}^{3} \frac{g_i}{4} \tag{2.48}$$

where:

S_i = actual or consensus forecast sales per share in year *i* where *i* = 0 to 3;

$Shares_i$= actual or consensus forecast shares on issue in year *i* where *i* = 0 to 3;

g_i = estimated growth in sales per share in year *i*;

g_n = initial growth in sales per share.

I estimate the long-term growth in sales per share ($\bar{g}$) according to the equation below:

$$\bar{g} = (1-p)r_e \tag{2.49}$$

where:

p = the dividend payout ratio, estimated according to the procedure previously documented; and

r_e = the continuously-compounded cost of equity capital.

3.4.4 Parameters relating to the uncertainty of revenue growth $(\sigma, \bar{\sigma}, \eta)$

I estimate the initial volatility of revenue growth (σ) as the standard deviation of revenue growth for each individual stock, for all years in which historical data is available, prior to portfolio formation. I then make estimate a time period- and industry-specific long-term volatility of revenue growth ($\bar{\sigma}$), by using data only for firms with at least five years of revenue growth. As with the estimated long-term margin, the exception to this requirement is valuations performed on 1997 and 1998 stocks. For these stocks, the long-term volatility of revenue growth was estimated using firms with just three and four years of growth observations.

Finally, I assume that the initial standard deviation of expected revenue growth (η_n) is equal to 0.10 for all firm-years. I make this assumption with reference to the mean estimate of initial revenue growth (g_n) for all firm years, which is primarily driven by analyst consensus forecasts. This mean estimate is 7.6 percent. For a firm with expected earnings growth of 0.076, $\eta_n = 0.10$ and a competitive advantage period of 30 years, this is equivalent to a 20 percent probability of negative expected revenue growth.

The use of a constant here raises the question as to whether a firm-specific, or time period- and industry-specific estimate could not be used, as was the case with estimating other parameters. The answer is that there is insufficient theory or evidence to show that this parameter would be different amongst firms or industries, or to estimate the magnitude of those differences. In the case of profit margin and parameters relating to the volatility of revenue growth ($\sigma, \overline{\sigma}$; as opposed to the volatility of expected revenue growth, η) I relied on economic arguments about long-term industry margins and volatility, and was able to measure these parameters using a large historical dataset. But estimating the parameter η on a firm-specific, or time period- and industry-specific basis is likely to induce greater estimation error, than simply using a market-wide estimate.

3.4.5 Cost of equity capital (r_e)

I estimate the cost of equity capital using the capital asset pricing model, which states that the required return to equityholders is the sum of the risk-free rate (r_f), plus the product of the firm's equity beta (β_e) and the market risk premium ($r_m - r_f$):

$$r_e = r_f + \beta_e \left(r_m - r_f\right) \qquad (2.50)$$

I estimate the risk-free rate as the yield on ten-year US Treasury bonds and the market risk premium at 6 percent. On average, the return to US equities has exceeded the average return to US Treasuries by over 7 percent from 1900-2002 (Dimson, Marsh and Staunton, 2003) and 8 percent from 1921 – 1996 (Jorion and Goetzmann, 1999). But these estimates exceed the average equity premium reported for global portfolios in those papers, and is substantially above the premium reported in other markets. Given the possibility that the performance of US equities was unusually strong during the 20th century, I use the more conservative figure of 6 percent in computing the required return to equityholders.

In estimating each firm's equity beta, I perform adjustments to the standard OLS regression technique relied upon in practice. This is to reduce the impact on unusually high or low equity betas, resulting from unusual trading. For each firm-year, and using data available prior to formation, I compute the ordinary least squares equity beta (OLS beta). The largest dataset of returns used includes all available monthly returns from January 1985 to December 2005. The beta calculation is the covariance of monthly returns on the stock and returns on the S&P500, divided by the variance of monthly returns on the S&P500.

$$\beta_{OLS} = \frac{COV(r_i, r_m)}{\sigma_m^2} \tag{2.51}$$

A long time-series of monthly returns was used in the computation of the equity beta, given the evidence in Gray, Hall, Bowman, Brailsford, Faff, Grundy, Officer and Smith (2005). They find that the ability of the capital asset pricing model to forecast equity returns is enhanced when a long time series of data is used, compared to the standard estimation window of 48 or 60 months of returns. The returns set used for my beta calculations also implies that the number of returns observations used in computing equity beta estimates differs according to firm-year. However, there is no reason to believe that equity betas estimated using a different number of returns months will be systematically biased. What is clear, is that estimates made using a longer series of returns reduces the standard error of those estimates.

I then estimate the equity beta by applying two constraints to the OLS beta. First, I make an adjustment first suggested by Blume (1971) and which is standard practice in beta estimates provided by Bloomberg. This adjustment takes the following form, which mitigates against the influence of extreme beta estimates, which are most likely to result from unusual trading in the stock, rather than very high or low systematic risk:

$$\beta_{adjusted} = \frac{1}{3} + \frac{2}{3}\beta_{OLS} \tag{2.52}$$

Again, the justification for this adjustment is the evidence of Gray et al, 2005. Their additional finding was that a Blume-type adjustment to the OLS beta estimate further enhances the ability of the capital asset pricing model to predict equity returns. Finally, I constrain the equity beta estimate to the range of 0 to 4, to further mitigate against the influence of negative or extremely high beta estimates. These constraints imply that the equity beta of each firm is estimated according to the following formula:

$$\beta_{OLS} = Max\left\{Min\left[\frac{1}{3} + \frac{2}{3} \times \frac{COV(r_i, r_m)}{\sigma_m^2}, 4\right], 0\right\} \tag{2.53}$$

These constraints on the estimate of beta are especially important, considering the purpose for which the beta estimate is being computed. The *DCF* and *Decision-tree valuations* are used to form investment portfolios, to determine whether they are useful from a portfolio management perspective. The cost of equity is the discount rate applied to forecast cash flows *and* determines the growth of those cash flows over the *CAP*. For a firm with a high dividend payout ratio, too low a discount rate will overstate value, resulting in an increased probability of the models suggesting the stock is relatively cheap. For the same firm, too high a discount rate has the opposite effect. But for a firm a low dividend payout ratio, the impact on value is dampened somewhat. Too low a discount rate increases the present value of a given set of forecast dividends, but reduces the magnitude of those forecasts, by reducing growth. In contrast, too high a discount rate flows through to inflated sales growth, but the resulting cash flows are reduced in present value terms.

3.4.6 Speed of adjustment parameter (κ)

Two variables in the *DCF* valuation model converge asymptotically to long-term expected values: (1) the revenue growth rate (g) converges to $\bar{g}$; and (2) the profit margin (m) converges to ($\bar{m}$). The speed of adjustment parameter (κ) is estimated as a function of T via the result that the half-life of these variables equals $\frac{\ln 2}{\kappa}$ (Schwartz and Moon, 2001). If we assume that the variables should revert to within 0.1 percent of normal levels at the end of the *CAP* (broadly consistent with the assumptions used by Bradshaw (2002) as shown below), the equation for the speed of adjustment parameter becomes:

$$\kappa = \frac{-\ln(0.001)}{T} \qquad (2.54)$$

My valuation estimates rely on an assumption that the competitive advantage period takes on values of 10, 20 or 30 years. A competitive advantage period in this range can be justified with reference to Bradshaw (2004). He used two versions of the residual income model to make estimates of intrinsic value. The first version was based on the same economic theory which underpins my valuations, that competitive pressures mean that long-term abnormal returns are expected to equal zero. Under the assumption that residual income is expected to revert to a long-term estimate of zero, he assumed that:

$$Residual\ income_i = \omega \times Residual\ income_{i-1} \qquad (2.55)$$

where:

ω = is referred to as the fade-rate; and

i = year i.

He made industry-specific estimates of this parameter with a linear regression of current period residual income on prior period residual income. His estimates for ω range from 0.51 to 0.80 and average 0.68.

If year n is the end of the explicit forecast period (five years in Bradshaw's case), then we can express the above equation as follows:

$$Residual\ income_i = \omega^{i-n} \times Residual\ income_n \tag{2.56}$$

Rather than estimate residual income, I estimate revenue growth and profit margin under the assumption that abnormal growth and profitability are expected to revert to zero over time. In my modelling, the parameter κ determines the rate of mean-reversion, according to the following equations:

$$\begin{aligned} g_i - \overline{g} &= e^{-\kappa(i-n)}(g_n - \overline{g}) \\ m_i - \overline{m} &= e^{-\kappa(i-n)}(m_n - \overline{m}) \end{aligned} \qquad (2.57)\ (2.58)$$

So, Bradshaw's fade-rate parameter (ω) is conceptually equivalent to $e^{-\kappa}$ in my modelling. And his range of parameter estimates is equivalent to an assumption that κ is in the range of 0.22 to 0.67. Solving Equation 2.54 for T with these estimates for κ implies estimates for T from 10 to 31 years. Adding Bradshaw's five-year explicit forecast period implies estimates for the competitive advantage period of around 15 to 36 years.

4 Preliminary analysis

One objective of this study is to establish the merits of *Decision-tree* valuation in forming investment portfolios of stocks with high expected revenue growth, but with significant uncertainty over their future prospects. But implementing *Decision-tree* valuations is computationally more complex than *DCF* valuations, and would therefore be pursued only if there is a reasonable chance that it will result in portfolio outperformance. Hence, in this section, I provide preliminary evidence, consistent with the literature cited in Section 2, that market prices exceed *DCF* valuations by an economically significant margin. This evidence is presented in Sub-section 4.2.

In Sub-section 4.3, I examine the association between theoretical values and market prices. I also assess the sensitivity of model valuations to increases in the competitive advantage period, volatility of revenue growth and the cost of equity capital, and compare value/price ratios to those computed by Bradshaw (2002).

I reiterate that my objective is not to fit a theoretical model to the data, but to assess the merits of fundamental equity investment. However, if there is no association between market prices and model valuations, it is unlikely that equity analysts will be persuaded to move away from a price-earnings approach. The research on analyst valuation techniques suggests that selecting the appropriate price-earnings ratio to use in setting target prices is based on heuristic decision-rules, rather than any formal model.

One potential explanation for this behaviour is that textbook models used to determine the appropriate ratio result in target prices materially below share prices. For example, under the constant growth dividend discount model, if reinvested earnings earn a return equal to the cost of capital, then the theoretical price-earnings multiple is the inverse of the cost of capital. If analysts relied on this theory, target prices would be based on price-earnings ratios of around 8 times for the period under study, as the mean cost of equity capital was 12.2 percent. This rule is unlikely to be implemented by analysts who observe market price-earnings ratios which average 22 times. The mean price-earnings ratio of 22 can be justified if the assumed *ROE* on reinvested earnings is around 15 percent (3 percent above the cost of capital). But there is no economic theory which suggests that firms are able to persistently achieve these above-normal returns.

Basically, my concern is that analysts are unlikely to utilise the results of a formal valuation model if theoretical valuations deviate materially from market prices, and this difference is persistent across time periods and industries. In my study, the median value/price ratio estimated under *Decision-tree* values reaches 0.85, assuming a competitive advantage period of 30 years. And it ranges from 0.84 – 1.03 for six of the 11 IBES industry sectors. So, while portfolio performance is similar, regardless of whether *DCF* or *Decision-tree* valuations are performed, this increases the chance that analysts will adopt a more formal model for setting target prices. Furthermore, measurement error would be diminished in the analyst setting, because analysts can make firm-specific judgements regarding parameter estimates.

4.1 Sample

The sample consists of 9427 firm-years over an 18-year period from 1987 to 2004. It is drawn from 1049 separate stocks that formed part of the NASDAQ Composite Index or the S&P500 as at 30 April 2004. The number of sample firms increases from 270 in 1987 to its peak of 942 in 2003. Datastream and Compustat, via Research Insight, were the source of all accounting, share price and index data. Consensus earnings and sales forecasts were obtained from IBES via Datastream. Descriptive statistics are presented in Table 2.1, partitioned according to cohort year and IBES industry sector.

An obvious constraint on sample size is the requirement that IBES consensus forecasts are available. Given that IBES consensus forecasts are typically only available for large, heavily-traded firms, this limits the external validity of the sample. However, its internal validity is likely to be enhanced. That is, the pricing of small thinly-traded securities is more likely to be affected by unusual trading, due to factors like short-selling restrictions or the actions of large stakeholders.

The sample used in Barron, Byard, Kile and Riedl (2002) shows just how small a percentage of firms and firm-years have significant analyst following and are likely to have reliable data. They documented an association between intangible assets of high-technology firms and the dispersion of analyst forecasts. The sample consisted of 451 firms with IBES forecast data drawn from 1986-1998, which enabled production of a data set of 1,103 firm-years. 49 percent of sample firms were from four industries, as defined by 2-digit SIC codes. These industries and the number of firms in the sample from the industry were Industrial Machinery (70), Chemicals and Allied Products (52), Electronic Equipment (50) and Business Services (including Software) (50).

The key parameters affecting the valuations are the initial and long-term revenue growth (g_n and $\overline{g}$), the initial and long-term profit margin (m_n and $\overline{m}$), the cost of equity capital (r_e) and the initial and long-term volatility of revenue growth (σ and $\overline{\sigma}$). The pooled data at the top of Table 2.1 shows that initial expectations for revenue growth and profit margin are highly variable across firm-years. The mean estimate of initial revenue growth is 7.6 percent, but has a standard deviation of 15.1 percent. The mean estimate for the initial margin is also 7.6 percent and has a standard deviation of 19.7 percent.

The most interesting feature of Panel A is the variation of initial revenue growth and profit margin expectations over time. In 1996, expectations for revenue growth peaked at 11.2 percent, and steadily declined to 4.1 percent by 2002. Average margin expectations followed the same pattern over time, peaking at 10.4 percent in 1997, but steadily declining to 3.7 percent by 2003. In contrast, the mean price-earnings and market-to-book equity ratios increased over this time period, peaking in 2002 and 2004, respectively. This evidence contradicts any assertion that the sudden rise and decline of equity values was due to inflated earnings forecasts prepared by analysts. There seems little question that the equities research and investment banking divisions of securities firms lacked independence, given that 10 brokerage houses were willing to enter into an $875 million settlement with the SEC. But there is no evidence that analyst expectations for profitability, taken as a whole, were responsible for inflated equity prices. For the broader market at least, analyst earnings forecasts due not support the assertion of Oxley (2002) who commented that, in relation to preferred clients involved in the flipping of IPOs, "their profits were gained at the expense of the average investor, whose only option was to buy the shares at the inflated aftermarket price."

However, the increase in mean price-earnings and market-to-book ratios does coincide with a sustained decline in interest rates. They are also associated with the changing nature of the sample over time, which is characterised by an increase in dispersion of profit margin. In 2003, the sample standard deviation of the initial margin peaked at 31.7 percent, which was 8.6 times the sample mean estimate of initial margin in that year (3.7 percent). The changing nature of the sample can also explain the gradual increase in the volatility of revenue growth. The mean estimate of initial volatility peaks at 24.1 percent in 2003. This was 5.9 times the mean estimate of revenue growth in that year (4.1 percent).

This increase in the volatility of revenue growth can be largely attributed to the Technology, Healthcare and Energy sectors, which comprise 30 percent of the sample. They had mean initial volatility estimates of 24.8, 19.8 and 26.9 percent, respectively. These sectors can also account for the increase in price-earnings and market-to-book ratios over time. Technology stocks had a mean price-earnings ratio of 34.3 times and a mean market-to-book ratio of 5.2 times.

In sum, the sample is drawn from a period of declining revenue growth and profitability, which coincided with a period of declining interest rates and rising equity prices. The volatility of initial revenue growth increased during this time due to the increased prominence of industries characterised by volatile revenue growth and profitability.

Table 2.1
Descriptive statistics

Table 2.1 presents descriptive statistics for 1049 US stocks contained in the S&P500 and NASDAQ indices from 1987 to 2004. The cost of equity capital (r_e) is estimated according to the Capital Asset Pricing Model [$r_e = r_f + \beta\,(r_m - r_f)$], where the risk-free rate is the yield on 10-year US Treasury bonds, obtained from Datastream; the market risk premium ($r_m - r_f$) is estimated at 6 percent; and the equity beta is estimated according to the procedure documented in Sub-section 3.4. The market-to-book equity ratio (*M/B*) is the ratio of the market price to the book value of equity per share. The price-earnings ratio (*P/E*) is the ratio of the market price to the IBES consensus earnings per share forecast. The market capitalisation (*MktCap*) is the product of the share price and the number of shares on issue as reported by IBES, for consistency with the IBES consensus earnings forecast. The initial and long-term growth rates in sales (g_n and $\overline{g}$), profit margins (m_n and $\overline{m}$) and volatility of sales growth (σ_n and $\overline{\sigma}$) are also estimated according to procedures documented in Sub-section 3.4. The risk-free rate, share price and earnings per share forecast are at 30 April each year. The variables which rely on financial statement data (sales growth, profit margin and volatility of sales growth) use the most recent financial statement information available prior to 31 December of the previous year. Panel A presents descriptive statistics by cohort year and Panel B presents the same statistics by IBES industry sector.

Panel A: Descriptive statistics by cohort year

Year	*n*	r_f	r_e	β	*M/B*	*P/E*	*Mkt Cap*	g_n	$\overline{g}$	m_n	$\overline{m}$	σ_n	$\overline{\sigma}$
Pooled summary													
Mean	9427	6.1	12.2	1.0	4.1	22.2	9.3	7.6	9.2	7.6	6.9	17.7	18.8
Med		5.7	12.1	1.0	2.5	16.2	2.7	7.1	9.3	7.1	6.4	12.5	17.3
Std		1.5	2.6	0.5	18.2	42.6	25.8	15.1	3.8	19.7	2.0	18.2	7.1
Means by year													
1987	270	8.2	14.4	1.1	2.8	15.9	4.4	5.8	9.0	7.9	6.8	10.8	11.4
1988	280	8.9	15.1	1.1	2.3	12.2	3.8	10.2	9.7	8.0	6.8	12.6	12.9
1989	289	9.0	15.3	1.1	2.4	12.2	4.2	13.0	10.2	7.8	6.7	12.8	13.6
1990	312	9.0	15.4	1.1	2.7	13.3	4.5	10.8	10.4	7.9	6.9	13.0	13.1
1991	326	8.0	14.5	1.1	2.9	15.9	5.2	8.9	9.5	7.7	7.1	12.8	12.9
1992	340	7.6	14.1	1.1	3.5	18.1	5.8	4.2	9.0	8.6	7.3	13.0	13.2
1993	342	6.0	12.5	1.1	3.5	17.8	6.2	6.4	8.0	9.2	7.3	12.9	13.1
1994	362	7.0	13.3	1.1	3.3	16.6	6.2	5.7	8.9	10.3	7.3	13.2	13.5
1995	378	7.1	13.2	1.0	3.7	16.0	7.1	10.7	9.2	9.8	7.3	13.4	13.5
1996	390	6.6	12.7	1.0	4.1	18.0	9.1	11.2	9.0	9.5	7.4	14.0	14.0
1997	583	6.7	12.3	0.9	4.4	19.1	7.9	9.0	9.5	10.4	7.1	14.3	15.4
1998	630	5.7	11.2	0.9	5.1	23.9	10.7	9.4	8.8	8.7	7.2	15.5	16.8
1999	684	5.4	11.4	1.0	5.1	26.0	12.9	8.1	9.0	8.3	6.8	18.2	17.6
2000	739	6.2	12.1	1.0	4.6	23.7	13.9	8.2	9.7	8.6	6.8	18.6	18.6
2001	776	5.3	11.3	1.0	4.2	25.6	12.7	7.9	9.4	7.6	6.6	20.7	20.7
2002	859	5.1	11.1	1.0	4.4	33.5	10.8	4.1	9.3	5.1	6.8	22.6	25.2
2003	942	3.9	10.2	1.1	3.3	26.1	8.8	4.1	8.6	3.7	6.7	24.1	26.8
2004	925	4.5	10.8	1.1	5.7	26.5	11.1	7.7	8.8	5.6	6.7	23.8	27.4
Mean	524	6.7	12.8	1.0	3.8	20.0	8.1	8.1	9.2	8.0	7.0	15.9	16.6
Med	384	6.7	12.6	1.1	3.6	18.0	7.5	8.1	9.1	8.2	6.9	13.7	13.8
Std	242	1.6	1.7	0.1	1.0	5.9	3.3	2.6	0.6	1.7	0.3	4.3	5.1
Medians by year													
1987	---	---	14.3	1.0	2.3	14.7	2.2	7.4	9.1	6.8	6.4	6.0	11.7
1988	---	---	15.2	1.1	1.9	11.5	2.0	10.5	9.9	6.5	6.4	8.5	13.0
1989	---	---	15.4	1.1	1.9	11.6	2.2	12.5	10.3	6.9	6.4	9.0	13.5
1990	---	---	15.5	1.1	2.0	11.9	2.1	9.1	10.2	6.7	6.6	9.4	13.3
1991	---	---	14.5	1.1	2.0	14.2	2.2	8.4	9.3	6.6	6.6	9.7	13.2
1992	---	---	14.1	1.1	2.3	15.8	2.6	4.0	8.9	7.6	6.7	10.4	13.3
1993	---	---	12.5	1.1	2.8	15.5	3.2	5.3	8.3	7.8	6.5	10.3	13.3
1994	---	---	13.3	1.1	2.7	14.8	3.2	5.2	8.9	8.8	6.4	10.2	13.7
1995	---	---	13.3	1.1	2.7	13.9	3.4	9.3	9.2	8.8	6.4	10.6	13.4
1996	---	---	12.9	1.1	3.1	15.9	4.3	9.9	9.0	8.8	6.8	10.5	14.2
1997	---	---	12.5	0.9	2.7	16.1	2.8	8.4	9.6	8.5	6.5	10.2	16.1
1998	---	---	11.4	0.9	3.5	20.0	3.5	8.3	9.1	7.7	6.5	11.7	16.7
1999	---	---	11.4	1.0	3.0	19.0	3.3	7.4	9.5	7.0	5.6	12.4	17.0
2000	---	---	12.1	1.0	2.6	15.2	2.6	7.1	10.4	7.2	5.7	12.9	16.8
2001	---	---	11.0	0.9	2.6	17.4	2.9	6.8	9.6	6.9	5.5	14.4	18.8
2002	---	---	10.7	0.9	2.6	20.2	2.2	3.6	9.5	6.3	5.4	16.3	26.1
2003	---	---	9.6	0.9	2.0	16.6	1.7	4.1	8.4	5.8	5.4	17.6	25.6
2004	---	---	10.3	0.9	2.7	19.1	2.9	7.3	8.7	6.6	5.2	18.3	27.0
Mean	---	---	12.8	1.0	2.5	15.7	2.7	7.5	9.3	7.3	6.2	11.6	16.5
Med	---	---	12.7	1.0	2.6	15.6	2.7	7.4	9.2	7.0	6.4	10.5	13.9
Std	---	---	1.8	0.1	0.4	2.7	0.7	2.4	0.6	0.9	0.5	3.2	4.9

Panel A: Descriptive statistics by cohort year (continued)

Year	n	r_f	r_e	β	M/B	P/E	Mkt Cap	g_n	$\overline{g}$	m_n	$\overline{m}$	σ_n	$\overline{\sigma}$
Standard deviations by year													
1987	---	---	1.4	0.3	1.7	9.8	8.4	21.4	4.1	5.7	1.9	14.3	4.6
1988	---	---	1.4	0.3	1.3	5.2	6.7	13.6	4.4	5.6	1.9	12.5	4.5
1989	---	---	1.4	0.3	1.5	4.9	7.0	13.4	4.2	4.8	1.8	11.5	4.1
1990	---	---	1.5	0.4	4.4	12.9	7.7	12.5	4.4	5.8	1.8	10.6	3.8
1991	---	---	1.5	0.4	2.7	7.7	9.2	10.3	4.2	5.8	1.8	9.8	3.6
1992	---	---	1.4	0.4	5.7	13.1	10.1	14.9	4.4	6.2	1.9	9.3	3.3
1993	---	---	1.4	0.3	2.9	9.3	9.6	13.3	3.9	6.4	1.8	9.1	2.9
1994	---	---	1.4	0.4	2.4	8.4	9.6	14.9	3.9	7.6	1.7	9.3	2.7
1995	---	---	1.5	0.4	4.6	10.2	11.4	14.0	3.7	6.7	1.8	12.3	2.8
1996	---	---	1.6	0.4	4.9	9.6	14.6	16.6	3.4	20.9	2.0	12.3	3.0
1997	---	---	1.7	0.4	15.3	18.5	18.3	15.6	3.2	13.0	1.9	15.2	3.4
1998	---	---	1.7	0.4	7.1	21.4	24.4	15.1	3.0	19.0	1.9	14.2	4.3
1999	---	---	1.8	0.4	8.5	44.4	33.6	16.2	3.6	13.1	2.1	22.1	4.4
2000	---	---	1.8	0.5	6.2	34.3	43.4	14.8	3.7	16.1	2.0	18.7	5.1
2001	---	---	2.4	0.6	7.2	51.7	36.1	16.1	3.6	23.0	2.1	22.4	4.6
2002	---	---	2.5	0.6	11.8	94.4	29.3	15.0	4.0	30.7	2.0	21.9	5.4
2003	---	---	3.0	0.8	6.6	53.7	25.3	14.1	4.0	31.7	2.0	22.5	5.5
2004	---	---	2.7	0.7	53.3	47.3	29.2	14.0	3.9	23.8	2.0	20.4	5.5
Mean	---	---	1.8	0.4	8.2	25.4	18.6	14.8	3.9	13.7	1.9	14.9	4.1
Med	---	---	1.5	0.4	5.3	13.0	13.0	14.9	3.9	10.3	1.9	13.4	4.2
Std	---	---	0.5	0.1	11.8	24.2	11.7	2.2	0.4	9.1	0.1	5.1	0.9

Panel B: Descriptive statistics by IBES industry sector

Year	n	r_f	r_e	β	M/B	P/E	Mkt Cap	g_n	$\overline{g}$	m_n	$\overline{m}$	σ_n	$\overline{\sigma}$
Pooled summary													
Mean	9427	6.1	12.2	1.0	4.1	22.2	9.3	7.6	9.2	7.6	6.9	17.7	18.8
Med		5.7	12.1	1.0	2.5	16.2	2.7	7.1	9.3	7.1	6.4	12.5	17.3
Std		1.5	2.6	0.5	18.2	42.6	25.8	15.1	3.8	19.7	2.0	18.2	7.1
Means by IBES industry sector													
Basic industries	680	6.3	12.3	1.0	2.9	19.5	5.0	5.1	8.1	6.9	5.6	15.4	14.9
Capital goods	901	6.0	12.0	1.0	3.0	19.6	9.1	6.4	8.9	5.7	5.1	18.2	18.3
Consumer durables	514	6.1	12.3	1.0	3.4	15.0	3.7	5.9	9.0	5.2	5.1	13.6	14.8
Consumer non-dur	868	6.3	12.1	1.0	6.0	18.2	10.6	7.2	8.1	8.1	6.5	13.7	14.6
Consumer services	1662	5.9	12.3	1.1	5.4	25.0	6.6	8.9	10.3	5.2	5.5	16.5	19.4
Energy	499	6.0	11.3	0.8	2.4	23.9	10.4	5.9	7.4	5.7	5.7	26.9	26.7
Finance	1090	6.3	12.4	1.0	2.7	13.7	12.7	3.4	8.4	16.8	9.2	16.6	16.6
Healthcare	1145	5.7	11.7	1.0	5.3	30.1	10.1	12.9	10.1	2.1	6.6	24.8	26.9
Technology	1208	6.0	13.5	1.4	5.2	34.3	12.7	12.1	12.6	9.2	8.7	19.8	20.7
Transport	148	6.6	12.9	1.1	2.1	14.9	7.1	5.2	9.4	6.7	6.7	10.8	11.5
Utilities	712	6.5	10.7	0.5	1.9	14.7	9.3	2.4	4.3	10.3	10.8	12.4	12.6
Mean	857	6.2	12.1	1.0	3.7	20.8	8.8	6.9	8.8	7.5	6.8	17.1	17.9
Med	868	6.1	12.3	1.0	3.0	19.5	9.3	5.9	8.9	6.7	6.5	16.5	16.6
Std	414	0.3	0.7	0.2	1.5	6.8	2.9	3.3	2.0	3.8	1.9	5.0	5.2
Medians by IBES industry sector													
Basic industries	---	6.2	12.2	1.1	2.1	16.2	2.6	4.6	8.3	6.2	5.6	11.3	12.7
Capital goods	---	5.7	11.8	1.0	2.5	15.5	2.2	5.4	9.0	5.8	5.1	13.7	18.1
Consumer durables	---	5.7	12.3	1.1	2.1	13.3	1.7	5.3	9.3	4.8	5.1	11.5	13.0
Consumer non-dur	---	6.0	12.2	1.0	3.6	16.4	3.4	6.3	7.8	7.0	6.5	10.7	11.9
Consumer services	---	5.4	12.1	1.1	2.9	18.2	1.7	8.5	10.2	4.7	5.2	9.6	18.8
Energy	---	5.7	11.1	0.8	2.1	17.9	3.0	6.4	7.9	6.5	5.0	23.3	26.4
Finance	---	6.2	12.3	0.9	2.1	12.4	5.3	5.2	8.3	13.0	9.9	12.4	14.3
Healthcare	---	5.4	11.5	1.0	3.5	20.5	1.2	10.9	9.9	9.4	6.5	17.0	28.9
Technology	---	5.7	13.2	1.3	3.4	24.0	2.0	10.5	12.6	8.1	9.0	16.0	17.0
Transport	---	6.6	13.1	1.1	1.9	13.5	5.5	5.8	9.5	6.3	6.8	10.9	11.0
Utilities	---	6.2	10.6	0.5	1.7	12.3	5.0	3.1	3.6	10.5	10.7	7.8	8.4
Mean	---	5.9	12.0	1.0	2.5	16.4	3.0	6.5	8.8	7.5	6.9	13.1	16.4
Med	---	5.7	12.2	1.0	2.1	16.2	2.6	5.8	9.0	6.5	6.5	11.5	14.3
Std	---	0.4	0.8	0.2	0.7	3.6	1.6	2.4	2.2	2.6	2.1	4.3	6.4
Standard deviation by IBES industry sector													
Basic industries	---	1.5	2.3	0.4	5.4	19.4	8.4	12.2	3.4	4.9	0.3	16.7	3.8
Capital goods	---	1.5	2.4	0.4	2.6	39.6	34.8	13.6	3.0	8.0	0.2	15.6	2.8
Consumer durables	---	1.5	2.5	0.4	9.1	9.0	7.0	12.1	3.2	5.4	0.1	8.9	3.5
Consumer non-dur	---	1.5	2.4	0.4	11.7	14.1	21.6	10.2	3.2	6.1	0.6	11.7	3.7
Consumer services	---	1.4	2.7	0.5	41.1	58.6	18.2	12.6	3.2	8.2	0.6	21.2	5.9
Energy	---	1.4	2.5	0.5	1.3	21.1	31.9	21.5	4.2	37.2	1.2	16.5	4.7
Finance	---	1.5	2.3	0.4	2.0	6.1	24.9	17.1	3.1	13.1	1.4	13.2	3.8
Healthcare	---	1.4	2.6	0.5	7.9	59.4	26.8	17.1	3.2	44.0	1.3	26.9	8.5
Technology	---	1.4	2.8	0.7	6.4	55.6	39.5	15.3	3.4	11.1	0.6	16.9	6.7
Transport	---	1.5	1.9	0.2	1.0	6.5	5.8	10.8	2.9	4.3	0.3	4.8	1.9
Utilities	---	1.5	2.0	0.3	1.1	43.1	16.7	15.1	3.1	4.8	0.2	13.8	6.5
Mean	---	1.5	2.4	0.4	8.2	30.2	21.4	14.3	3.3	13.4	0.6	15.1	4.7
Med	---	1.5	2.4	0.4	5.4	21.1	21.6	13.6	3.2	8.0	0.6	15.6	3.8
Std	---	0.1	0.3	0.1	11.5	21.5	11.4	3.3	0.4	13.8	0.5	5.9	2.0

4.2 Preliminary evidence that embedded options are valued by the market

This section presents preliminary evidence that an economically meaningful proportion of equity value is comprised of embedded options. I measure the association between equity prices and the present value of a perpetuity stream of sustainable earnings, estimated as the product of sustainable margin and sales per share with both variables scaled by book value. The evidence is consistent with high-growth, high-volatility sectors trading at a price-to-book ratio which incorporates a growth premium. But these sectors also have a higher proportion of their market-to-book ratio which is *not* explained by the present value of sustainable earnings. Further, this unexplained portion of the market-to-book ratio is positively associated with the volatility of revenue growth, which is what we would expect to observe if embedded options are valued by the market. In sum, there is prima facie evidence that market prices incorporate some estimate of options value.

The estimation procedure relies upon the premise that market prices contain information about the appropriate competitive advantage period, with higher prices signalling that the market expects the firm to report abnormal revenue growth or margins for a longer period of time. Using linear regression, I estimate the *DCF* and embedded option components of equity value, as a multiple of book value of equity per share, on a time-period and industry-specific basis.

This technique is consistent with that used to simultaneously estimate growth and the cost of equity capital of US-listed firms from 1981-1998 (Easton, Taylor, Shroff and Sougiannis, 2002). In their regression, the price-book ratio was the independent variable and the dependent variable was the firm's aggregate four-year earnings, presented as:

$$\frac{X_{jcT}}{B_{j0}} = \gamma_0 + \gamma_1 \frac{P_{j,0}}{B_{j0}} + e_{j0} \qquad (2.59)$$

where:

X_{jcT} = aggregate four year cum-dividend earnings for firm *j*;

B_j = book value per share for firm *j*; and

$Pj,_0$ = share price of firm *j*.

Easton et al (2002) interpret γ_0 as the expected four-year growth in residual income and $\gamma_0 + \gamma_1$ as the expected four-year rate of return. In other words, they interpret the intercept term as the component of the four-year return attributable to growth and the coefficient on the price-book ratio as the component of return attributable to earnings from existing assets. But the Easton et al model assumes that share price makes no allowance for the value of embedded options. If embedded options are valuable, then the intercept term can be interpreted as the sum of the expected four year growth in residual income plus the expected return from the exercise of embedded options. The model above is further limited by the need for cumulative four-year earnings to be positive. Negative earnings make this equation nonsensical.

In the model presented below, the price-book ratio is a component of the dependent variable. The independent variable represents the present value of earnings after the explicit forecast period under the assumption that the firm has already achieved steady state. I interpret the intercept term as the market-implied value of embedded options, as a multiple of book value; and the beta coefficient as a multiple of book value which is contingent upon revenue growth and the competitive advantage period.

The values of both these estimates have clear economic meaning for market participants making an assessment of whether the market is mispriced. For example, if the value of embedded options in an industry is unreasonably high, perhaps in comparison to historical data, this suggests that the market is overly-optimistic about the prospects of successful expansion plans or commercialisation of new products. In another example, investors could determine the set of revenue growth and *CAP* parameters which would be required to justify a given multiple. The reasonableness of these estimates could be evaluated with reference to historical data. The regression model is derived as follows.

I assume that the value of equity is the sum of the present value of expected dividends, plus some option value, where the present value of expected dividends is estimated using Equation 2.1. This implies that:

$$\begin{aligned}\text{Equity value} &= \text{Option value} + \text{DCF value}\\ &= \text{Option value}\\ &\quad + \sum_{i=1}^{n} \frac{p_i m_i S_i}{e^{r_e i}} \qquad (2.60)\\ &\quad + pS_n \sum_{i=n+1}^{n+T-1} \frac{\left[\overline{m} + e^{-\kappa(i-n)}(m_n - \overline{m})\right]\exp\left[\overline{g}(T-1) + (g_n - \overline{g})\sum_{i=n+1}^{n+T-1} e^{-\kappa(i-n)}\right]}{e^{r_e i}}\\ &\quad + \overline{m}S_n \frac{\exp\left[\overline{g}T + (g_n - \overline{g})\sum_{i=n+1}^{n+T} e^{-\kappa(i-n)}\right]}{r_e e^{r_e(n+T-1)}}\end{aligned}$$

The last two terms of the equation can be factorised using the factor $\frac{\overline{m}S_n e^{\overline{g}}}{r_e e^{r_e n}}$. This factor represents the present value of perpetual cash flows in the case where the firm reaches its steady state by the end of the explicit forecast period. After factorising the last two terms of the above equation and subtracting the present value of expected dividends from the explicit forecast period from both sides of the equation, we have (2.61):

$$\text{Equity value} - \sum_{i=1}^{n} \frac{p_i m_i S_i}{e^{r_e i}} = \text{Option value} + \frac{\overline{m} S_n e^{\overline{g}}}{r_e e^{r_e n}} \left\{ \begin{array}{l} p \sum_{i=n+1}^{n+T-1} \left[1 + e^{-\kappa(i-n)} \left(\frac{m_n}{\overline{m}} - 1 \right) \right] \exp\left[\overline{g}(T-2) + (g_n - \overline{g}) \sum_{i=n+1}^{n+T-1} e^{-\kappa(i-n)} - r_e (i-n) \right] \\ + \exp\left[(\overline{g} - r_e)(T-1) + (g_n - \overline{g}) \sum_{i=n+1}^{n+T} e^{-\kappa(i-n)} \right] \end{array} \right\}$$

The equation above expresses equity value per share as the sum of the value of expected dividends during the explicit forecast period, the value of expected dividends after the explicit forecast period (as a multiple of $\frac{\overline{m} S_n e^{\overline{g}}}{r_e e^{r_e n}}$) and an estimated option value. I then divide both sides of the equation by the book value of equity per share. Dividing this equation by book value of equity per share allows me to estimate the market-implied value of embedded options as a multiple of book value per share. I selected book value of equity per share as the appropriate scaling factor, because it represents an estimate of the historical cost of the firm's existing equity. The use of a scaling factor from the income statements assumes that the value of embedded options is associated with some current level of sales or earnings. But sales and earnings are the current payoffs from previous investments. It is more likely that option value is associated with the amount of equity previously invested in the firm, which is the cost of purchasing the embedded options. Thus, the equation is (2.62):

$$\frac{\text{Price} - \sum_{i=1}^{n} \frac{p_i m_i S_i}{e^{r_e i}}}{\text{Book value}} = \frac{\text{Option value}}{\text{Book value}} + \frac{\frac{\overline{m} S_n e^{\overline{g}}}{r_e e^{r_e n}}}{\text{Book value}} \left\{ \begin{array}{l} p \sum_{i=n+1}^{n+T-1} \left[1 + e^{-\kappa(i-n)} \left(\frac{m_n}{\overline{m}} - 1 \right) \right] \exp\left[\overline{g}(T-2) + (g_n - \overline{g}) \sum_{i=n+1}^{n+T-1} e^{-\kappa(i-n)} - r_e (i-n) \right] \\ + \exp\left[(\overline{g} - r_e)(T-1) + (g_n - \overline{g}) \sum_{i=n+1}^{n+T} e^{-\kappa(i-n)} \right] \end{array} \right\}$$

I then run the following regression on data for each year and IBES industry group in order to estimate two parameters – the option value per dollar of book value, and a multiple of $\frac{\overline{m} S_n e^{\overline{g}}}{r_e e^{r_e n}}$, which is a function of growth, profit margin, the cost of equity, and the remainder of the competitive advantage period. The regression model is:

$$\frac{\text{Price}_j - \sum_{i=1}^{n} \frac{p_{i,j} m_{i,j} S_{i,j}}{e^{r_e i}}}{\text{Book value}_j} = \alpha + \beta \frac{\frac{\overline{m}_j S_{n,j} e^{\overline{g}_j}}{r_{e,j} e^{r_{e,j} n}}}{\text{Book value}_j} \qquad (2.63)$$

where:

$Price_j$ = share price of firm j; and
Book $value_j$ = book value of equity per share for firm j.

The observations are weighted by market capitalisation in order to mitigate against the impact of firms with very low reported book values, and correspondingly very high price-to-book ratios, which are more likely to be in error. This is done because the impact on the regression of very low versus very high book values is asymmetric. A firm with an unusually low reported book value has more potential to become a significant observation when the regression line is fitted, given that it has the potential to lie a material distance away from the other points. Further, when these observations were given equal weight in the regression, this influence was apparent via significant increases in the intercept term and reduced explanatory power. Thus, the weighting scheme mitigates *against* the argument that equity prices incorporate some value for embedded options.

An alternative is to weight firms by their book value of equity. But the result of this weighting by book value is to place greater weight on firms whose value is comprised by a higher proportion of tangible assets. This is not the intention of the weighting scheme, which is simply to reduce the impact of influential observations with an above-average risk of misstatement. The assumption employed is that this risk is reduced the larger the size of the firm. As with the unweighted case, when the regression was performed after weighting by book value of equity, intercepts typically increased and explanatory power was reduced. This is consistent with the price-to-book ratio having a closer relationship with the value of sustainable earnings for larger firms, compared to smaller firms.

The results of this regression model, run on a time-period and industry-specific basis, are presented in Table 2.2. I interpret the intercept term as an estimate of option value per dollar of book value, and β as a factor which encompasses the market's expectations for margin growth, revenue growth, the cost of equity capital, reinvestment policy and the competitive advantage period. Figure 2.5, Panel A presents the mean annual coefficients by industry for the regressions in which the adjusted-R^2 is at least 10 percent. Note that in the case of weighted least squares regression, this statistic is not bounded in the range of 0 to 1. So we cannot interpret this statistic as the proportion of variation in the dependent variable that is explained by the independent variables. However, this cutoff is simply used to limit the conclusions drawn from regressions whose explanatory power is particularly poor. The radius of the points in the figure is equal to the standard error of the coefficients, which provides a visual representation of the uncertainty surrounding these estimates.

Table 2.2

Relationship between market value and the value of sustainable earnings

Table 2.2 presents the results of the weighted least squares regression model $\frac{\text{Price}_j - \sum_{i=1}^{n} \frac{p_{i,j} m_{i,j} S_{i,j}}{e^{r_e i}}}{\text{Book value}_j} = \alpha + \beta \frac{\frac{\overline{m}_j S_{n,j} e^{\overline{g}_j}}{r_{e,j} e^{r_e, jn}}}{\text{Book value}_j}$ where, for each firm j, Price = share price at 30 April; Book value = actual book value per share at 30 April; p_i = dividend payout ratio in year i; m_i = profit margin in year i; S_i = estimated sales per share forecast in year i; r_e = the required return to equityholders; $\overline{m}$ = the estimated long-term profit margin; S_n = estimated sales per share in year n; $\overline{g}$ = estimated long-term sales growth; and $n = 3$. The term $\sum_{i=1}^{n} \frac{p_{i,j} m_{i,j} S_{i,j}}{e^{r_e i}}$ is an estimate of the present value of expected dividends during the explicit forecast period of three years. The factor $\frac{\overline{m}_j S_{n,j} e^{\overline{g}_j}}{r_{e,j} e^{r_e, jn}}$ is an estimate of the present value of expected dividends into perpetuity, if the firm earned just its cost of capital on reinvested earnings in every year after the explicit forecast period. Observations have been weighted by market capitalisation. Significance levels in the individual years refer to the *t*-tests of the intercept term against a null hypothesis of zero, and the coefficient on the independent variable against a null hypothesis of one. The third last row of the table reports the mean of the intercept term, coefficient on the independent variable, number of observations and adjusted-R^2; and the second-last row reports the mean after excluding years in which the adjusted-R^2 is less than 10 percent. In these cases, each year is treated as an independent observation, and the *t*-tests are conducted on the distribution of the coefficients. The last row reports the results of a pooled regression. ***, ** and * correspond to significance at the 1, 5 and 10 percent level, respectively. The sample used in the regressions comprises 9054 firm-years from 1987-2004, which represents 96 percent of the full sample. The excluded firms had negative or missing values for the book value of equity.

	Basic industries				Capital goods				Consumer durables				Consumer non-durables			
	Intercept	Beta	n	A-R^2	Intercept	Beta	n	A-R^2	Intercept	Beta	n	A-R^2	Intercept	Beta	n	A-R^2
1987	1.77 ***	0.75	25	15	2.14 ***	-0.03 ***	25	-4	2.59 ***	-0.12 ***	16	17	2.11 ***	0.95	31	19
1988	2.07 ***	-0.40 ***	23	2	1.63 ***	0.24 ***	28	0	2.62 ***	-0.35 ***	15	7	2.70 ***	0.20 ***	31	0
1989	1.40 ***	0.35 ***	25	16	2.14 ***	-0.34 ***	27	14	2.32 ***	-0.29 ***	13	0	2.61 ***	0.24 ***	31	7
1990	1.95 ***	-0.42 *	24	-3	2.09 ***	-0.21 ***	27	-1	2.14 ***	-0.29 ***	17	8	3.13 ***	0.53	34	4
1991	-2.97 **	6.23 ***	25	47	2.13 ***	-0.33 ***	27	1	2.24 ***	-0.48 ***	18	20	2.65 ***	1.29	34	15
1992	1.82 ***	0.85	26	1	2.40 ***	-0.40 ***	28	1	2.70 ***	-0.60 ***	18	13	3.76 ***	0.60	34	2
1993	2.38 ***	0.35	26	-3	2.29 ***	0.21 ***	28	7	4.29 ***	-0.29 ***	19	0	1.89 **	1.17	35	15
1994	2.34 ***	0.57	27	6	2.23 ***	0.47	28	1	5.12 ***	-1.43 ***	18	19	3.39 ***	0.69	36	2
1995	2.17 ***	0.40 *	27	1	2.35 ***	0.25 ***	30	2	2.31 ***	0.03 ***	18	-6	2.66 ***	1.25	36	29
1996	3.23 ***	0.21 *	30	-2	2.97 ***	0.13 ***	31	-2	3.35 ***	-0.46 ***	20	32	-1.83	6.32 **	34	16
1997	1.43 ***	1.28	43	19	3.42 ***	0.14 ***	61	-1	3.19 ***	-0.58 ***	35	32	3.01 ***	2.36 ***	52	53
1998	1.93 ***	1.19	46	6	4.10 ***	0.45 *	64	2	4.27 ***	-0.42 ***	35	12	5.23 ***	1.63 *	58	27
1999	2.01 ***	1.31	46	16	5.90 ***	-0.35 *	68	-1	2.48 ***	0.22 ***	34	2	3.42 **	3.16 ***	56	30
2000	1.49 ***	1.36	49	20	10.10 ***	-3.98 ***	73	7	1.41 ***	0.53 **	34	14	2.56 **	2.69 ***	60	46
2001	1.89 ***	0.81	49	13	3.75 ***	0.15 **	73	-1	0.84	1.64 ***	45	83	5.25 ***	1.13	61	9
2002	1.91 ***	0.66	52	10	2.69 ***	0.51 *	84	3	3.60 ***	0.04 **	42	-2	4.58 ***	1.63 *	65	26
2003	1.52 ***	0.70 *	55	27	2.33 ***	0.31 ***	87	5	3.82 ***	-0.07 ***	46	-1	5.89 ***	0.42 **	70	2
2004	2.12 ***	0.61 **	53	15	2.73 ***	0.44 ***	82	7	2.05 **	0.51 **	44	8	2.16 **	2.55 ***	71	50
Mean	1.69 ***	0.93	36	11	3.19 ***	-0.13 ***	48	2	2.85 ***	-0.13 ***	27	14	3.06 ***	1.60	46	20
Adj mean	1.19 *	1.49	41	21	2.14	-0.34	27	14	2.86 ***	-0.21 ***	27	27	2.59 ***	2.27 **	48	30
Pooled	1.89 ***	0.79 **	651	11	3.62 ***	0.10 ***	871	0	0.24	1.18 ***	487	52	3.31 ***	1.89 ***	829	24

Table 2.2

Relationship between market value and the value of sustainable earnings (continued)

	Consumer Services				Energy				Finance				Healthcare			
	Intercept	Beta	n	A-R^2	Intercept	Beta	n	A-R^2	Intercept	Beta	n	A-R^2	Intercept	Beta	n	A-R^2
1987	3.91 ***	0.03 ***	35	-3	1.58 ***	0.40	12	-7	1.03 **	0.68	33	16	5.18 ***	-0.10 ***	21	-4
1988	2.74 ***	-0.04 ***	36	-3	1.35 ***	0.19 *	11	-8	1.01 ***	0.50 *	39	7	2.62 ***	0.56	22	4
1989	3.14 ***	-0.04 ***	38	-3	1.17 ***	0.47	15	7	1.07 ***	0.55 ***	41	42	3.67 ***	0.01 **	22	-5
1990	3.03 ***	0.21 ***	40	0	1.79 ***	-0.16 **	14	-7	1.64 ***	0.25 **	44	-1	4.66 ***	0.25	24	-3
1991	2.34 ***	0.85	40	20	2.40 ***	-0.57 ***	14	21	1.79 ***	0.06 ***	51	-2	4.20 ***	1.06	21	4
1992	3.30 ***	0.45 *	41	3	1.82 ***	0.08	18	-6	1.80 ***	0.32 ***	54	1	5.26 ***	0.24	26	-3
1993	2.71 ***	0.74	43	33	2.87 ***	-0.79 ***	16	11	1.75 ***	0.46 **	53	6	3.41 ***	0.85	27	19
1994	3.57 ***	0.30 ***	47	11	2.34 ***	-0.50 ***	21	3	1.65 ***	0.31 ***	59	3	2.36 ***	1.63	29	31
1995	3.69 ***	0.06 ***	51	-1	2.31 ***	-0.27 ***	21	5	1.37 ***	0.52 **	58	10	5.08 ***	0.00 ***	33	-3
1996	3.90 ***	0.16 ***	50	-1	2.70 ***	-0.10 ***	21	-3	1.79 ***	0.25 ***	63	25	6.12 ***	0.02 ***	36	-3
1997	3.92 ***	0.24 ***	100	1	3.11 ***	-0.12 ***	30	-1	2.47 ***	0.38 ***	62	6	5.55 ***	2.06	64	4
1998	5.39 ***	0.21 ***	106	1	2.95 ***	0.22 ***	31	4	3.33 ***	0.45 ***	64	9	10.56 ***	0.13 ***	77	0
1999	3.85 ***	1.55 ***	131	44	2.79 ***	0.73	34	11	3.76 ***	0.18 ***	66	-1	12.58 ***	0.04 ***	87	-1
2000	5.68 ***	1.04	135	8	2.93 ***	0.37 ***	40	51	3.21 ***	1.03	73	5	12.46 ***	-1.40 ***	101	3
2001	4.44 ***	0.67 **	150	10	2.79 ***	0.59	45	6	3.06 ***	0.65	71	6	10.82 ***	-1.08 ***	104	5
2002	1.53 ***	2.17 ***	179	80	1.99 ***	0.83	41	9	2.61 ***	0.45 **	79	3	7.69 ***	-0.30 ***	127	2
2003	2.16 ***	0.97	193	24	2.10 ***	0.00 ***	47	-2	2.11 ***	0.27 ***	86	1	6.20 ***	-0.16 ***	143	0
2004	2.82 ***	0.73	184	8	2.74 ***	0.02 ***	48	-2	2.01 ***	0.38 ***	88	7	4.97 ***	0.54 ***	149	8
Mean	3.45	0.57 ***	89	13	2.32 ***	0.08 ***	27	5	2.08 ***	0.43 ***	60	8	6.30 ***	0.24 ***	62	3
Adj mean	2.69 ***	1.10	106	35	2.75 ***	-0.06 *	26	24	1.32 ***	0.50 **	49	23	2.89	1.24	28	25
Pooled	2.93 ***	1.25 ***	1599	30	2.31 ***	0.28 ***	479	7	2.72 ***	0.31 ***	1084	2	7.78 ***	0.11 ***	1113	0

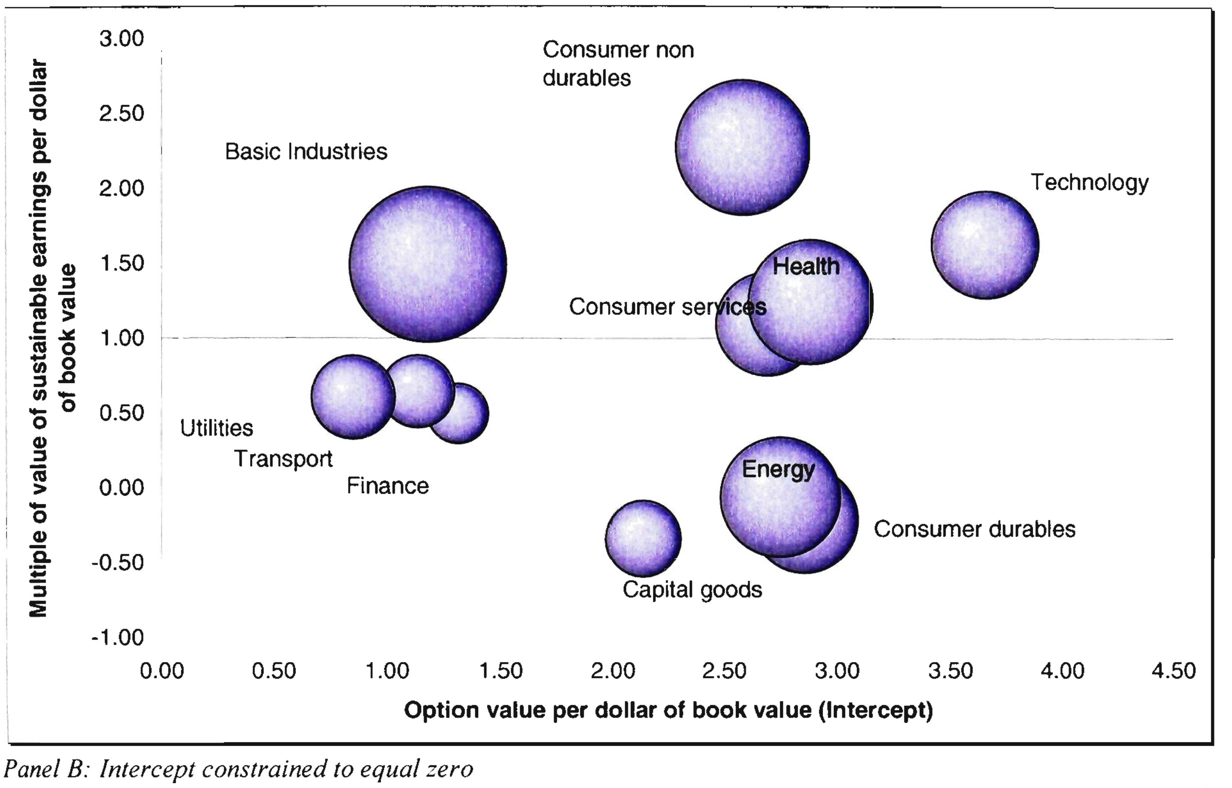
	Technology				Transport				Utilities			
	Intercept	Beta	n	A-R^2	Intercept	Beta	n	A-R^2	Intercept	Beta	n	A-R^2
1987	3.71 ***	0.02	24	-5	0.90 ***	0.78	8	69	0.89 ***	0.37 ***	32	11
1988	2.88 ***	-0.07 **	25	-4	0.90 **	0.36 *	8	10	0.60 ***	0.61 **	32	26
1989	1.31	1.01	27	7	0.96	0.53	8	-1	1.04 ***	0.17 ***	32	62
1990	3.10 ***	0.46	32	-1	0.97 **	0.35 **	8	20	0.93 ***	0.50 ***	33	35
1991	3.45 ***	-0.09 *	34	-3	1.44 ***	-0.06 ***	8	-10	1.17 ***	0.24 ***	34	5
1992	1.74 ***	1.17	40	34	2.46 ***	-0.44 ***	8	6	1.42 ***	0.08 ***	34	-2
1993	2.60 **	1.44	42	14	1.87 *	0.48	7	-8	1.48 ***	0.24 ***	34	1
1994	4.63 ***	0.03	43	-2	1.47 **	0.90	7	59	1.33 ***	0.36 ***	35	17
1995	2.54 **	1.23	48	11	1.99 ***	0.08 ***	8	-12	0.98 ***	0.66 *	37	22
1996	5.10 ***	0.58	53	0	2.38 ***	-0.10 ***	8	-9	0.23	1.59 *	37	41
1997	6.27 ***	-0.03 ***	75	-1	1.87 ***	0.19 ***	8	10	1.91 ***	0.10 ***	40	-1
1998	3.60 ***	2.43 ***	84	76	1.84 ***	0.36 **	8	28	2.68 ***	0.19 ***	39	-1
1999	6.50 ***	2.98 ***	87	23	2.27 **	0.09	7	-20	3.60 ***	0.09 ***	42	-2
2000	14.09 ***	0.45	95	-1	1.35	0.44	8	-7	4.55 ***	-0.28 ***	48	-1
2001	5.41 ***	1.22	97	15	1.64	0.40	8	-11	3.48 ***	-0.09 ***	48	-1
2002	4.90 ***	0.16 ***	108	-1	1.56 *	0.41	8	-10	2.12 ***	-0.03 ***	46	-2
2003	3.20 ***	0.91	126	13	1.58 ***	0.22 **	8	-1	1.73 ***	0.04 ***	47	-2
2004	3.94 ***	0.81	126	5	0.77 **	1.11	7	75	1.91 ***	0.05 ***	45	-2
Mean	4.39 ***	0.82	65	10	1.57 ***	0.34 ***	8	11	1.78 ***	0.27 ***	39	11
Adj mean	3.66 ***	1.63 *	75	27	1.14 ***	0.64 **	8	44	0.86 ***	0.61 *	34	31
Pooled	5.73 ***	1.87 ***	1166	17	1.70 ***	0.29 ***	80	7	2.05 ***	0.27 ***	695	4

Figure 2.5

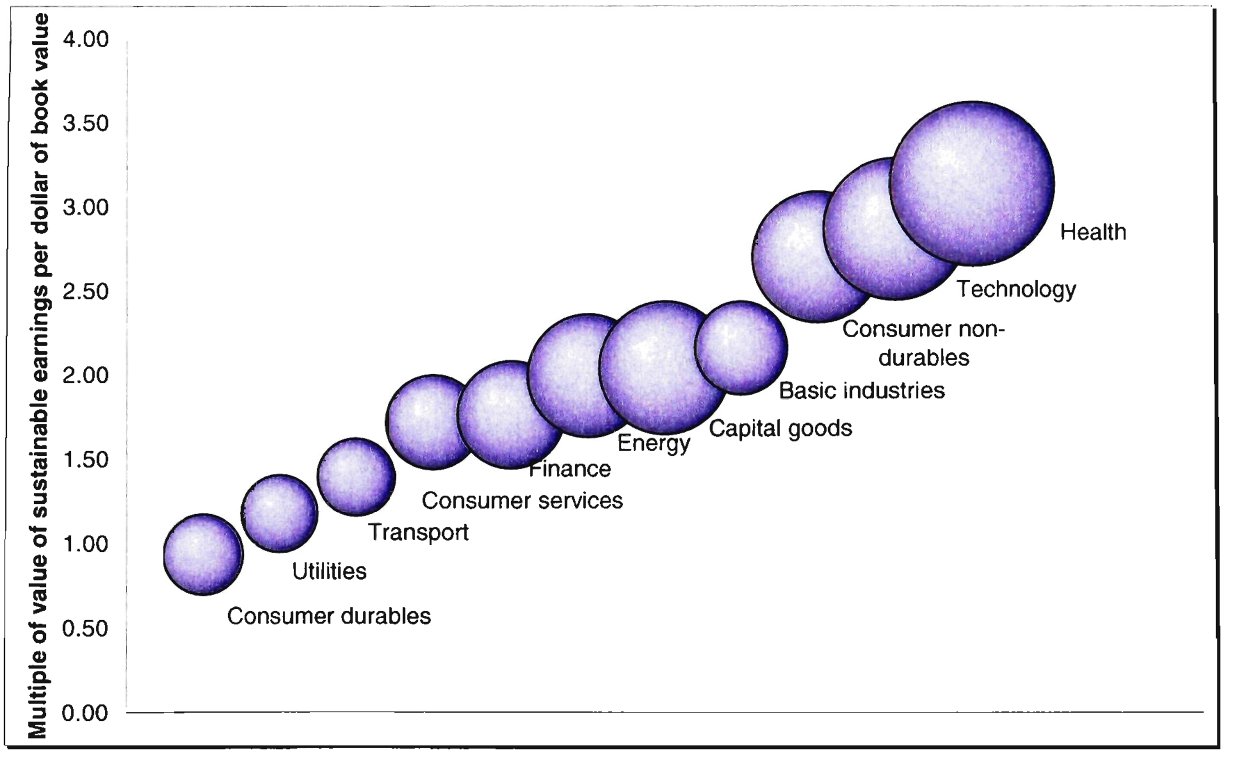
Estimated option value and market-implied valuation multiples by IBES industry sector

Figure 2.5 illustrates the mean annual intercept terms and beta coefficients from the regression analysis summarised in Table 2.2. In computing these means, I exclude regressions in which the adjusted-R^2 is less than 10 percent. Mean intercept terms are presented on the horizontal axis and mean beta coefficients are presented on the vertical axis. The radius of the points is equal to the standard error of the beta coefficient. Panel B presents comparable results from regression analysis in which the intercept term was constrained to equal zero. Values along the horizontal axis are equal to zero. The chart is displayed in this format so that the y-axis data can be directly compared to the chart above. The sample comprises 9427 firm-years from 1987-2004, which represents 1049 individual firms.

Panel A: Intercept unconstrained



Panel B: Intercept constrained to equal zero



Theoretically, the beta coefficient is primarily a function of growth expectations, while the intercept term is an estimate of the option value per dollar of book value. A comparison of Figure 2.5, Panel A with the industry descriptive statistics suggests that the coefficients do capture these economic constructs. I grouped the sample into four clusters, based on the industry mean estimates for initial revenue growth and the initial volatility of revenue-growth. These clusters were:

1. High-growth, high volatility sectors – Technology and Healthcare;
2. High-growth, low-volatility sectors – Consumer services and consumer non-durables;
3. Low-growth, high volatility sectors – Capital goods, Energy and Finance; and
4. Low-growth, low volatility sectors – Consumer durables, Transport, Basic industries and Utilities.

I then compared the mean intercept terms and beta coefficients from the regression analysis amongst these clusters, weighted by firm-year. The results, presented in Table 2.3, suggest there is an association between expected revenue growth and the beta coefficient, as well as an association between volatility of revenue growth and the intercept term. The mean beta coefficient for the high-growth firms is 1.4, compared to the mean of 0.4 for the low-growth firms; and the mean intercept term for the high-volatility firms of 2.6 is greater than the mean intercept term of 2.1 for the low volatility firms. In addition, high-growth firms also have high intercept terms, as the level of growth and its expected volatility are positively correlated.

Table 2.3
Revenue growth and volatility parameters compared to estimated option value per dollar of book value and the multiple of the present value of sustainable earnings

I partitioned the 11 IBES industry sectors into two roughly equal-sized groups according to their firm-year weighted initial growth estimates. Then, I partitioned each of those two groups into two roughly equal-sized groups based on their initial volatility estimates. Hence, there are four approximately equal-sized groups partitioned according to growth and volatility. For each group, I computed the firm-year weighted intercept term and beta coefficients from the annual results of the regression model presented as Equation 2.63. These results only include those cases in which the adjusted-R^2 was at least 10 percent. These results are presented in columns 7-8. In column 9, I present the results of the same analysis in which the intercept term was constrained to equal zero. The data is comprised of 9427 firm-years from 1987-2004, attributable to 1049 individual firms.

Industry cluster	N	Initial growth	Long-term growth	Initial vol	Long-term vol	Inter-cept	Beta	Beta (int=0)
1. High-growth, high-volatility (Technology, Healthcare)	2353	12.5	11.4	22.2	23.7	3.3	1.3	3.0
2. High-growth, low volatility (Consumer services, consumer non-dur)	2530	8.3	9.5	15.5	17.8	2.7	1.5	2.1
3. Low-growth, high volatility (Capital goods, Energy, Finance)	2490	5.0	8.4	19.2	19.2	1.9	0.1	1.9
4. Low-growth, low volatility (Consumer dur, Transport, Basic, Utilities)	2054	4.4	7.1	13.6	13.8	1.5	0.7	1.5
High-growth	4883	10.3	10.4	18.8	20.6	3.0	1.4	2.5
Low-growth	4544	4.7	7.8	16.7	16.8	1.7	0.4	1.7
High-volatility	4843	8.6	9.8	20.7	21.4	2.6	0.7	2.4
Low-volatility	4584	6.5	8.5	14.7	16.0	2.1	1.1	1.8

I repeated this analysis after suppressing the intercept term in the regression. This allows a comparison of beta coefficients under the assumption that the market places zero value on embedded options, which is the assumption underlying *DCF* valuation models. I performed this analysis because of the low explanatory power of several of the regressions, as well as the number of cases in which the estimated beta coefficient was significantly less than one. It seems unreasonable to think that the market would value sustainable earnings at less than their value into perpetuity. So, perhaps the intercept terms from the original analysis do not capture any option value, and are simply the result of a poorly-fitted regression model. These beta coefficients are presented in Panel B of Figure 2.5. Their firm-year weighted means are presented in the final column of Table 2.3.

We observe a similar association between growth prospects and the beta coefficient when the intercept is constrained to equal zero. High-growth industries have a mean estimate of 2.5, compared to 1.7 for low-growth industries. But we also see a positive association between the beta coefficient and the volatility of revenue growth. If stocks are priced entirely as the present value of expected future cash flows, we would not expect to see this association. If the volatility of revenue growth is positively associated with the cost of equity capital, we would expect to see the opposite result – more volatile stocks would trade on lower multiples.

In sum, there is evidence to support the premise that stock prices incorporate some option value, in addition to their discounted cash flow valuations. Market-to-book equity ratios are positively associated with the present value of a perpetuity stream of sustainable earnings, and this association is strongest for high-growth industries. But the unexplained component of the market-to-book equity ratio is associated with the volatility of revenue growth. Further, when this unexplained term is constrained to equal zero, there in a positive association between the market-to-book equity ratio and the initial volatility of revenue growth.

This is contrary to what would be expected if value was entirely due to the present value of expected future cash flows. In that case, volatility would have a non-negative impact on the cost of capital, so there would be a zero or inverse relationship between volatility and the market-to-book ratio. However, in a real options framework, volatility has a positive impact on value, which is consistent with the data.

4.3 Relationship between valuations and market prices

Before evaluating portfolio performance, I discuss the relationship between model prices and market prices, particularly the impact of industry differences and the assumption of the competitive advantage period. As discussed in Section 2, there is every reason to expect market prices to diverge significantly from model prices. Parameter estimates which can be used to justify share prices at a given point in time will be highly volatile. But parameter estimates made independently of share price will, by construction, be relatively more stable. For example, the IBES consensus forecast that we observe at any point in time is an average of estimates which are entered into the database over some preceding period. So the initial estimates for revenue growth and margin are akin to a moving average of unobservable point-in-time forecasts.

Nevertheless, it is useful to assess the impact of changing parameter estimates on model valuations, and determine ranges of estimates which justify share prices. This provides an indication of whether, in practice, parameter estimates can be made with enough certainty to be relied upon. Tables 2.4 to 2.7 present the results of a detailed analysis of the association between market prices and valuations. The analysis is presented for the pooled sample, by cohort year and by IBES industry sector. I discuss the salient features of this data with reference to both the level and dispersion of model prices. I also discuss the estimated percentage of equity value attributed to real options, which I refer to as *Real option%*.

Model prices from my study can be compared with those of Bradshaw (2004). He performed residual income valuations on 4421 firms using information available at the start of each month from 1994-1998. This resulted in 46,209 valuations. Recall that my sample consists of 9,427 valuations on 1049 firms, using information available at 30 April each year from 1987-

2004. 2343 of these valuations are drawn from the period which overlaps with Bradshaw. He computed residual income valuations under two alternative assumptions. First, he assumed that residual income declines to zero according to an industry-specific fade-rate. This is analogous to my assumption that revenue growth and margins revert to long-term expected values over time. In addition, his assumed rate of decline in residual income approximates my assumption that the competitive advantage period is in the range of 10-30 years. His second version of the residual income model assumed that residual income at the end of the explicit forecast period was maintained into perpetuity. This is equivalent to the assumption that, in the terminal state, the firm is able to earn above-average returns into perpetuity.

Comparing the value/price estimates for 1994-1998, we see that Bradshaw's median value/price ratio of 0.59 is broadly comparable to my median estimates from the *DCF* valuations of 0.47 – 0.54. The difference can be largely attributable to my higher median cost of equity assumption (13 percent versus 11 percent). However, my estimates exhibit more dispersion. This is to be expected, given that my valuations incorporate the mean reversion of two parameter estimates. This means that the standard error associated with an intrinsic value estimate will aggregate the error in individual parameter estimates.

Table 2.4
Valuation relative to price

This table compares value/price ratios from my study with those of Bradshaw (2004). He performed residual income valuations on 4421 firms using information available at the start of each month from 1994-1998. This resulted in 46,209 valuations. My sample consists of 9,427 valuations on 1049 firms, using information available at 30 April each year from 1987-2004. 2343 of these valuations are drawn from the period which overlaps with Bradshaw. Bradshaw computed residual income valuations under two alternative assumptions: (1) residual income declines to zero; and (2) residual income at the end of the explicit forecast period is maintained into perpetuity. The first section of the table summarises Bradshaw's findings. The second and third sections summarise my value/price ratios under two valuation models (*DCF* and *Decision-tree*) and three assumptions regarding the competitive advantage period (10, 20 or 30 years). I present data for the full sample, as well as for the sub-sample from 1994-1998, the time period to which Bradshaw's valuations relate. The final two sections of the table summarise my value/price ratios according to IBES industries, under the assumption that the competitive advantage period is 30 years.

	Mean	Standard deviation	Median
Bradshaw (2004): 1994-1998			
Residual income value/price (residual income declines to zero)	0.67	0.48	0.59
Residual income/price (perpetual growth)	0.96	0.73	0.77
Cost of equity	0.11	0.04	0.11
Market capitalisation ($m)	3,763	10,125	874
Book-to-market ratio	0.46	0.28	0.41
Hall (2005): 1994-1998			
DCF/price (CAP=10)	0.71	0.83	0.47
DCF/price (CAP=20)	0.80	1.05	0.50
DCF/price (CAP=30)	0.93	1.55	0.54
DTV/price (CAP=10)	0.77	0.93	0.51
DTV/price (CAP=20)	1.00	1.48	0.60
DTV/price (CAP=30)	1.45	3.07	0.71
Cost of equity	0.12	0.02	0.13
Market capitalisation ($m)	8,477	17,811	3,378
Book-to-market ratio	0.40	0.29	0.34
Hall (2005): 1987-2004			
DCF/price (CAP=10)	0.78	1.01	0.49
DCF/price (CAP=20)	0.84	1.16	0.52
DCF/price (CAP=30)	0.94	1.61	0.54
DTV/price (CAP=10)	0.89	1.17	0.55
DTV/price (CAP=20)	1.22	1.88	0.67
DTV/price (CAP=30)	1.99	5.43	0.85
Cost of equity	0.12	0.03	0.12
Market capitalisation	9,250	25,814	2,727
Book-to-market ratio	0.48	0.39	0.39
Hall (2005)			
Hall (2005): 1987-2004 *DCF*/price (CAP=30)			
Basic industries	0.85	1.31	0.53
Capital goods	0.90	1.28	0.50
Consumer durables	1.15	1.84	0.73
Consumer non-durables	0.89	1.14	0.55
Consumer services	1.08	1.76	0.58
Energy	0.98	2.08	0.40
Finance	0.82	1.17	0.49
Healthcare	0.80	1.67	0.36
Technology	0.83	1.51	0.44
Transport	0.96	0.96	0.59
Utilities	1.28	2.34	0.88
Hall (2005): 1987-2004 DTV/price (CAP=30)			
Basic industries	1.44	3.59	0.70
Capital goods	1.68	3.27	0.79
Consumer durables	1.69	2.77	1.00
Consumer non-durables	1.34	1.96	0.73
Consumer services	2.40	7.81	1.03
Energy	2.93	7.54	0.97
Finance	1.19	1.88	0.65
Healthcare	3.24	7.98	0.89
Technology	1.85	4.00	0.84
Transport	1.24	1.28	0.73
Utilities	1.98	5.63	1.04

Now consider Bradshaw's valuations under the assumption that residual income at the end of the explicit forecast period continues into perpetuity. In this instance, the median value/price ratio reaches 0.77 and the mean estimate is 0.96. Therefore, in the event that firms can make investments which perpetually earn above their cost of capital, the median value/price ratio increases by 31 percent. Co-incidentally, this is exactly the same increase in the median value/price ratio that occurs when I estimate *Decision-tree* valuations instead of *DCF* valuations, under an assumed *CAP* of 30 years. In this instance the median value/price ratio increases from 0.54 to 0.71. There are four alternative explanations for this result:

1. Equity investors incorporate some estimate of value for embedded options, therefore pricing stocks at a premium to their *DCF* value.

2. The economic argument that long-term expected returns on investment equal the cost of capital is wrong, and firms are able to persistently earn abnormal returns. This is contrary to the evidence of Bradshaw (2004) and Dechow, Hutton and Sloan (1999) who document the diminishing residual income of listed firms over time.

3. The equity market persistently over-estimates the growth prospects of listed firms. At first glance this appears consistent with the outperformance of value stocks relative to growth stocks. However, *DCF* valuations do not approach market prices, even for value stocks. If market prices consistently exceeded *DCF* valuations because of investors extrapolating past growth too far into the future, we would observe *DCF* valuations of value stocks approaching market prices.

4. The cost of equity capital is significantly lower than the values assumed in deriving the valuations presented above. This argument was made by Fama and French (2002) and Claus and Thomas (2001) with reference to actual growth rates and those expected by equity analysts, and finds theoretical support from Mehra and Prescott (1985). The two empirical papers made estimates of the equity risk premium in the range of 3-4 percent. For comparison purposes, I computed the default risk premium on the Lehman Brothers BB-rated bond index, relative to 10-year US Treasuries. Using annual redemption yields from April 1990 to April 2004, I estimated this spread at 3.16 percent. Now say we compute expected returns, rather than the yield differential, by allowing for a default rate of 1.21 percent and a recovery rate of 39.05 percent (Elton, Gruber, Agrawal and Mann, 2001). In this instance, the expected return differential is 2.31 percent. It seems implausible that equity investors now require a risk premium only marginally above BB-rated bonds, when compared to historical data.

The evidence presented in Table 2.4 cannot directly counter explanations 2-4 above. But it does provide additional support for research into valuation techniques which estimate the value of embedded options.

In Tables 2.5 and 2.6, I present further detailed statistics on *DCF* valuations relative to price (*DCF/P*) and *Decision-tree* valuations relative to price (*DTV/P*). Both *DCF* and *Decision-tree* valuations can reach extreme levels at the upper and lower end so I am primarily concerned with median ratios. Referring to Panel C of Table 2.6, we see there is little industry difference in the median DTV/price ratio. Six IBES industry sectors have a median DTV/price ratio in the range of 0.80-1.04 (Consumer durables, Consumer services, Energy, Healthcare, Technology and Utilities). Another four IBES industry sectors have median DTV/price ratios from 0.70-0.79 (Basic industries, Capital goods, Consumer non-durables and Transport).

However, the median *DCF*/price ratio shows significant dispersion amongst industry sectors. Across the 11 sectors, the standard deviation of the median value/price ratios is similar (0.15 for *DCF*/price and 0.14 for DTV/price). But, when compared to the mean estimates of 0.55 and 0.85, we see that the coefficient of variation is 0.27 for *DCF* valuations and 0.17 for *Decision-tree* valuations. Interestingly, the three sectors with the lowest *DCF*/price ratios were classified as high-volatility sectors in the analysis presented in Sub-section 4.2 (Healthcare, Energy and Technology). These sectors had median *Decision-tree* value/price ratios in the range of 0.84-0.97. This provides support for theory underlying real options analysis, that volatility is positively associated with value.

Tables 2.5 and 2.6 also present four other statistics which provide useful information regarding the impact of using *Decision-tree* valuations in practice. In column 8 I provide descriptive statistics on *Real option%*, which is equal to the proportion of the *Decision-tree* valuation which exceeds the *DCF* valuation. I interpret this variable to be the percentage of equity value attributable to real options. In the study presented in Chapter 3 I use this variable to explain IPO underpricing, arguing that it is a proxy for information asymmetry amongst investors, and between issuers and investors. The median estimate for *Real option%* increases from 11 to 32 percent as the competitive advantage period increases from 10 to 30 years.

In columns 9-14 I provide additional descriptive statistics relating to the dispersion of model valuations relative to market prices. I compute the squared percentage error (*SPE*) and the absolute percentage error (*APE*) as follows:

$$SPE = \left(\frac{Value - Price}{Price} \right)^2 \quad (2.64) \qquad APE = \left| \frac{Value - Price}{Price} \right| \quad (2.65)$$

In computing the summary statistics relating to the squared percentage error I compute the square root of these statistics, so their magnitude can be compared to those relating to the absolute percentage error. For example, I compute the square root of the mean squared percentage error as:

$$SMSPE = \sqrt{\sum_{i=1}^{n}\left(\frac{Value - Price}{Price}\right)^2}$$

for n firms in the particular sub-sample.

I also computed the percentage of valuations which were within 30 percent of share price. Summary statistics referring to this calculation are presented in the final two columns. In Table 2.7, I present this information on a year-by-year basis for the Technology and Healthcare sectors.

A number of conclusions can be reached. First, increasing the assumed competitive advantage period increases the dispersion of value relative to price. But this increase is confined to the more extreme observations. For the *Decision-tree* valuation model, the median absolute percentage error is 56-58 percent for all three assumptions and slightly lower than the 59-60 percent reported for *DCF* valuations. Second, the assumed competitive advantage period which provides a close match between theoretical value and price varies across time periods and industries. I do not draw broad conclusions from this data as it is not my intention to fit model valuations to market prices. However, it is interesting to observe the following for the Technology and Healthcare sectors:

- In April 1999, the median absolute percentage error for the Technology sector was 57 percent when a *Decision-tree* valuation was performed, and that valuation assumed a competitive advantage period of 30 years. A *DCF* valuation, or a shorter assumed competitive advantage period, would have increased the median percentage error to 72 percent.
- In April 2003, the median absolute percentage error for the Healthcare sector was 97 percent under the same valuation assumptions, but would have been reduced to 64 percent with a decrease in the assumed *CAP* to 20 years.

In the modelling which underlies the Chapter 3 analysis, I estimate *Real option%* under the *CAP* assumption which minimises the difference between market prices of IPOs and *Decision-tree* values. For the purposes of this Chapter, I simply note there are likely to be significant differences in the appropriate *CAP* to be used in practice, given the sensitivity of valuation to this assumption.

Table 2.5
Model fit analysis by cohort year

Table 2.5 summaries the relationship between Discounted Cash Flow, *Decision-tree* valuations and market prices as at 30 April of each year. Columns 2-4 of each panel summarise prices, *DCF* valuations and *Decision-tree* valuations. Columns 5-7 summarise the relationship between these valuations, via computations of *DCF* value relative to price (*DCF/P*), *Decision-tree* value relative to price (*DTV/P*) and *Real option%* (1 – *DCF* value/*DTV*). Columns 8-13 present statistics which summarise the variance between model valuations and market prices. For the two valuation methods (*DCF* and DTV) I compute the squared percentage error (SPE), the absolute percentage error (APE) and the percentage of valuations within 30 percent of the market price. The definitions of these statistics are presented in Sub-section 4.3. Panels A, B and C present the analysis under the assumptions that the competitive advantage period is 10, 20 or 30 years, respectively.

Panel A: Competitive advantage period = 10 years

Cohort year	*N*	*P*	*DCF*	*DTV*	*DCF/P*	*DTV/P*	*RO%*	*SPE*		*APE*		*% in 30% of P*	
								DCF	*DTV*	*DCF*	*DTV*	*DCF*	*DTV*
Pooled summary													
Mean(sum n)	9427	21.81	14.05	15.99	0.78	0.89	11	103	117	68	71	20	22
Median	---	17.50	8.51	9.57	0.49	0.55	9	60	58	60	58	---	---
St Dev	---	16.90	23.77	28.25	1.01	1.17	9	261	298	77	93	---	---
Means by year													
1987	270	12.12	8.68	9.09	0.74	0.77	4	98	103	62	63	25	26
1988	280	10.99	8.80	9.43	0.81	0.86	5	63	66	50	50	29	30
1989	289	12.11	10.57	11.33	0.84	0.90	6	79	84	51	52	33	34
1990	312	11.85	9.72	10.32	0.83	0.87	5	63	66	50	51	32	31
1991	326	13.03	10.31	10.90	0.79	0.83	5	73	76	54	54	30	30
1992	340	14.70	8.66	9.12	0.64	0.67	5	72	74	59	58	18	19
1993	342	16.52	11.08	11.69	0.68	0.72	5	68	70	55	55	20	21
1994	362	16.53	10.11	10.62	0.62	0.65	5	67	67	58	57	19	19
1995	378	17.76	12.87	13.58	0.77	0.82	5	94	100	60	60	26	27
1996	390	21.98	14.99	16.00	0.72	0.77	6	79	83	58	59	27	27
1997	583	20.49	12.55	13.50	0.74	0.81	7	99	108	69	70	19	19
1998	630	27.00	15.69	17.18	0.70	0.77	9	90	101	67	68	19	21
1999	684	26.61	15.67	17.22	0.77	0.87	10	114	127	75	78	18	18
2000	739	26.31	14.64	16.19	0.80	0.89	11	102	114	75	79	17	18
2001	776	26.63	16.69	19.16	0.96	1.10	13	176	198	91	97	15	17
2002	859	25.99	14.92	18.12	0.71	0.87	19	99	117	72	75	16	19
2003	942	20.93	17.12	21.14	1.03	1.30	21	128	165	81	94	21	22
2004	925	28.72	17.83	22.12	0.67	0.84	21	75	88	63	65	17	21
Mean	524	19.46	12.83	14.26	0.77	0.85	9	91	100	64	66	22	23
Med	384	19.13	12.71	13.54	0.77	0.84	6	85	94	61	61	19	21
Std	242	6.26	3.16	4.23	0.10	0.15	6	28	35	12	14	6	5
Medians by year													
1987	---	9.90	4.70	4.88	0.52	0.53	3	56	56	56	56	---	---
1988	---	8.82	5.54	5.91	0.64	0.66	5	46	45	46	45	---	---
1989	---	10.15	6.23	6.57	0.65	0.69	5	44	42	44	42	---	---
1990	---	9.25	5.79	5.99	0.67	0.72	5	45	44	45	44	---	---
1991	---	10.88	6.31	6.57	0.61	0.63	4	50	50	50	50	---	---
1992	---	12.25	5.68	5.89	0.46	0.49	5	59	58	59	58	---	---
1993	---	13.36	7.45	7.81	0.51	0.53	5	53	51	53	51	---	---
1994	---	14.12	6.79	7.24	0.45	0.48	5	58	56	58	56	---	---
1995	---	16.30	8.91	9.15	0.56	0.59	5	51	49	51	49	---	---
1996	---	19.51	10.08	10.56	0.54	0.56	6	54	55	54	55	---	---
1997	---	18.44	8.20	8.68	0.45	0.49	7	63	62	63	62	---	---
1998	---	23.48	10.03	11.02	0.43	0.47	8	65	63	65	63	---	---
1999	---	22.31	8.91	9.82	0.42	0.47	9	66	64	66	64	---	---
2000	---	21.33	8.84	9.77	0.44	0.49	9	68	67	68	67	---	---
2001	---	23.79	9.78	11.01	0.45	0.52	11	68	65	68	65	---	---
2002	---	22.10	9.09	10.94	0.42	0.50	17	67	63	67	63	---	---
2003	---	17.06	10.32	13.10	0.59	0.72	18	62	61	62	61	---	---
2004	---	24.90	11.23	13.94	0.45	0.55	20	62	58	62	58	---	---
Mean	---	16.55	7.99	8.83	0.51	0.56	8	58	56	58	56	---	---
Median	---	16.68	8.52	8.92	0.51	0.53	5	59	57	59	57	---	---
St Dev	---	5.61	1.97	2.63	0.09	0.09	5	8	8	8	8	---	---

Panel A: Competitive advantage period = 10 years (continued)

Cohort year	*N*	*P*	*DCF*	*DTV*	*DCF/P*	*DTV/P*	*RO%*	*SPE*		*APE*		*% in 30% of P*	
								DCF	*DTV*	*DCF*	*DTV*	*DCF*	*DTV*
Standard deviations by year													
1987	---	9.27	14.84	15.83	0.94	1.01	4	245	264	76	82	---	---
1988	---	8.69	9.48	10.36	0.60	0.64	5	91	99	38	43	---	---
1989	---	9.14	13.39	14.50	0.78	0.83	5	188	201	61	66	---	---
1990	---	8.92	11.22	12.12	0.61	0.65	3	94	103	39	43	---	---
1991	---	9.29	12.15	13.08	0.70	0.74	3	131	138	50	53	---	---
1992	---	10.23	8.70	9.23	0.62	0.66	3	126	135	41	45	---	---
1993	---	11.38	13.06	13.86	0.60	0.65	3	109	120	40	44	---	---
1994	---	10.81	11.57	12.05	0.55	0.58	3	87	93	34	37	---	---
1995	---	10.73	13.75	14.54	0.92	0.98	3	224	243	73	80	---	---
1996	---	13.10	18.59	20.15	0.74	0.80	3	150	165	53	59	---	---
1997	---	13.44	15.13	16.35	0.95	1.06	4	217	252	71	82	---	---
1998	---	17.09	19.50	22.11	0.85	0.98	5	169	213	61	74	---	---
1999	---	19.34	28.32	31.06	1.12	1.26	6	253	288	86	100	---	---
2000	---	21.16	33.12	36.39	1.00	1.13	7	171	203	69	82	---	---
2001	---	18.79	30.25	35.40	1.76	1.98	7	444	494	151	173	---	---
2002	---	18.40	23.28	30.73	0.95	1.16	9	198	246	68	90	---	---
2003	---	16.04	34.13	43.03	1.28	1.62	9	252	326	100	135	---	---
2004	---	19.39	27.14	34.38	0.68	0.86	8	106	148	41	59	---	---
Mean	---	13.62	18.76	21.40	0.87	0.98	5	181	207	64	75	---	---
Median	---	12.24	14.99	16.09	0.85	0.98	4	170	202	61	70	---	---
St Dev	---	4.39	8.44	10.74	0.30	0.37	2	87	100	28	35	---	---

Panel B: Competitive advantage period = 20 years

Cohort year	*N*	*P*	*DCF*	*DTV*	*DCF/P*	*DTV/P*	*RO%*	*SPE*		*APE*		*% in 30% of P*	
								DCF	*DTV*	*DCF*	*DTV*	*DCF*	*DTV*
Pooled summary													
Mean (sum for n)	9427	21.81	15.06	21.61	0.84	1.22	24	117	190	71	90	21	24
Median	---	17.50	8.96	11.81	0.52	0.67	20	59	56	59	56	---	---
St Dev	---	16.90	27.00	47.82	1.16	1.88	18	320	511	94	167	---	---
Means by year													
1987	270	12.12	10.24	11.87	0.88	1.02	9	151	190	74	82	23	25
1988	280	10.99	9.86	11.66	0.91	1.06	12	79	98	55	62	33	31
1989	289	12.11	12.20	14.57	0.99	1.18	13	110	139	59	68	35	34
1990	312	11.85	10.68	12.53	0.93	1.09	12	80	98	56	64	28	29
1991	326	13.03	11.08	12.98	0.85	0.99	12	84	100	56	61	30	32
1992	340	14.70	8.87	10.13	0.68	0.78	12	80	90	62	63	18	23
1993	342	16.52	11.43	13.11	0.72	0.84	12	69	82	55	57	20	26
1994	362	16.53	10.44	11.87	0.66	0.77	12	71	79	58	59	22	25
1995	378	17.76	14.07	16.38	0.88	1.03	12	128	159	63	69	29	31
1996	390	21.98	16.97	20.44	0.84	1.02	13	97	127	63	72	28	27
1997	583	20.49	13.63	16.70	0.82	1.04	17	119	171	72	82	19	21
1998	630	27.00	17.55	22.75	0.78	1.05	20	105	160	70	83	21	22
1999	684	26.61	17.29	23.29	0.85	1.23	22	132	213	79	102	19	20
2000	739	26.31	15.70	20.83	0.86	1.19	23	113	174	79	97	20	19
2001	776	26.63	18.78	29.51	1.06	1.60	28	207	325	98	131	17	21
2002	859	25.99	15.05	25.70	0.72	1.27	38	98	195	72	97	16	20
2003	942	20.93	17.35	30.43	1.03	1.92	42	127	276	81	138	20	23
2004	925	28.72	18.45	31.86	0.69	1.25	42	76	142	62	82	19	26
Mean	524	19.46	13.87	18.70	0.84	1.13	19	107	157	67	82	23	25
Med	384	19.13	13.85	16.54	0.85	1.06	13	102	150	63	77	21	25
Std	242	6.26	3.34	7.14	0.12	0.28	11	34	67	12	24	6	5
Medians by year													
1987	---	9.90	4.85	5.27	0.53	0.57	8	56	55	56	55	---	---
1988	---	8.82	6.06	6.84	0.69	0.77	11	45	46	45	46	---	---
1989	---	10.15	6.69	7.94	0.70	0.84	12	43	41	43	41	---	---
1990	---	9.25	6.37	7.12	0.69	0.80	11	47	50	47	50	---	---
1991	---	10.88	6.55	7.11	0.65	0.72	11	50	49	50	49	---	---
1992	---	12.25	5.87	6.42	0.45	0.52	11	60	57	60	57	---	---
1993	---	13.36	7.71	8.74	0.54	0.62	12	52	49	52	49	---	---
1994	---	14.12	7.06	8.00	0.47	0.52	12	57	53	57	53	---	---
1995	---	16.30	9.45	10.22	0.61	0.69	12	48	46	48	46	---	---
1996	---	19.51	11.36	12.81	0.58	0.67	13	55	54	55	54	---	---
1997	---	18.44	8.51	10.13	0.47	0.58	17	63	60	63	60	---	---
1998	---	23.48	10.58	12.89	0.45	0.56	19	64	61	64	61	---	---
1999	---	22.31	9.71	12.28	0.46	0.57	21	65	62	65	62	---	---
2000	---	21.33	9.61	11.97	0.45	0.59	21	68	67	68	67	---	---
2001	---	23.79	10.36	14.18	0.48	0.67	26	66	63	66	63	---	---
2002	---	22.10	9.13	14.24	0.42	0.67	38	67	60	67	60	---	---
2003	---	17.06	10.61	17.46	0.59	1.00	39	62	60	62	60	---	---
2004	---	24.90	11.97	20.45	0.47	0.79	42	60	53	60	53	---	---
Mean	---	16.55	8.47	10.78	0.54	0.68	18	57	55	57	55	---	---
Median	---	16.68	8.82	10.17	0.53	0.67	12	59	55	59	55	---	---
St Dev	---	5.61	2.13	4.10	0.10	0.13	11	8	7	8	7	---	---
Standard deviations by year													
1987	---	9.27	24.37	32.62	1.51	1.90	8	427	527	132	172	---	---
1988	---	8.69	11.55	14.57	0.79	0.98	9	136	178	57	76	---	---
1989	---	9.14	17.14	21.38	1.10	1.38	10	277	343	94	122	---	---
1990	---	8.92	12.97	16.63	0.79	0.98	8	142	186	56	75	---	---
1991	---	9.29	13.83	17.48	0.83	1.01	8	170	207	62	79	---	---
1992	---	10.23	9.40	11.23	0.73	0.88	7	143	176	50	65	---	---
1993	---	11.38	13.34	16.04	0.63	0.80	7	115	157	43	58	---	---
1994	---	10.81	11.51	13.20	0.63	0.76	7	109	140	41	53	---	---
1995	---	10.73	14.82	18.03	1.28	1.59	8	402	498	112	143	---	---
1996	---	13.10	22.60	29.99	0.95	1.27	9	198	277	73	105	---	---
1997	---	13.44	16.89	22.18	1.18	1.71	10	329	557	95	150	---	---
1998	---	17.09	25.65	38.28	1.03	1.60	12	212	396	78	136	---	---
1999	---	19.34	36.30	51.90	1.31	2.12	14	311	502	106	187	---	---
2000	---	21.16	34.50	46.28	1.13	1.73	15	207	381	82	145	---	---
2001	---	18.79	40.22	85.83	2.07	3.20	15	516	790	182	298	---	---
2002	---	18.40	24.61	58.68	0.94	1.93	17	191	475	67	169	---	---
2003	---	16.04	35.35	66.27	1.28	2.61	17	244	570	98	240	---	---
2004	---	19.39	26.68	50.12	0.69	1.40	16	113	295	44	116	---	---
Mean	---	13.62	21.76	33.93	1.05	1.55	11	236	370	82	133	---	---
Median	---	12.24	19.87	26.08	1.03	1.55	9	203	362	76	129	---	---
St Dev	---	4.39	9.76	21.53	0.36	0.65	4	119	183	36	65	---	---

Panel C: Competitive advantage period = 30 years

Cohort year	*N*	*P*	*DCF*	*DTV*	*DCF/P*	*DTV/P*	*RO%*	*SPE*		*APE*		*% in 30% of P*	
								DCF	*DTV*	*DCF*	*DTV*	*DCF*	*DTV*
Pooled summary													
Mean (sum for n)	9427	21.81	16.60	34.82	0.94	1.99	36	161	552	79	154	22	24
Median	---	17.50	9.35	15.03	0.54	0.85	32	60	58	60	58	---	---
St Dev	---	16.90	36.19	157.3	1.61	5.43	22	580	2284	93	530	---	---
Means by year													
1987	270	12.12	12.62	17.17	1.12	1.58	16	263	454	96	132	21	23
1988	280	10.99	11.20	15.36	1.04	1.40	20	115	173	65	87	32	31
1989	289	12.11	14.13	19.72	1.19	1.68	22	171	274	73	107	31	32
1990	312	11.85	11.74	15.94	1.07	1.44	20	117	182	68	91	27	28
1991	326	13.03	11.88	16.00	0.92	1.24	21	107	155	61	77	31	34
1992	340	14.70	9.22	11.83	0.75	1.01	20	108	161	69	78	16	25
1993	342	16.52	11.85	15.44	0.76	1.03	20	77	117	57	66	24	30
1994	362	16.53	10.83	13.80	0.72	0.95	21	85	118	61	68	22	25
1995	378	17.76	15.62	21.09	1.03	1.44	21	207	321	73	98	29	29
1996	390	21.98	19.68	29.06	1.02	1.52	22	142	267	76	111	27	27
1997	583	20.49	15.15	23.10	0.95	1.51	27	172	350	81	118	21	20
1998	630	27.00	20.41	35.13	0.91	1.65	32	141	362	79	130	22	20
1999	684	26.61	19.68	39.03	0.98	2.19	34	171	721	88	184	20	21
2000	739	26.31	17.18	31.03	0.96	1.94	36	145	464	86	159	19	19
2001	776	26.63	22.96	60.73	1.24	2.96	42	308	956	114	253	18	21
2002	859	25.99	15.65	47.76	0.75	2.39	53	113	773	75	192	17	22
2003	942	20.93	17.81	52.69	1.06	3.46	57	138	838	85	277	20	23
2004	925	28.72	19.24	50.57	0.72	2.17	58	80	381	63	152	20	27
Mean	524	19.46	15.38	28.64	0.96	1.75	30	148	393	76	132	23	25
Med	384	19.13	15.38	22.10	0.96	1.58	22	139	336	74	114	21	25
Std	242	6.26	3.96	15.50	0.16	0.67	14	62	262	14	61	5	5
Medians by year													
1987	---	9.90	5.14	6.21	0.52	0.60	16	57	55	57	55	---	---
1988	---	8.82	6.48	7.57	0.71	0.90	19	46	47	46	47	---	---
1989	---	10.15	7.48	9.60	0.77	0.98	21	44	46	44	46	---	---
1990	---	9.25	6.69	7.98	0.71	0.91	20	50	49	50	49	---	---
1991	---	10.88	6.69	8.16	0.66	0.80	20	49	47	49	47	---	---
1992	---	12.25	5.92	6.93	0.46	0.58	19	59	57	59	57	---	---
1993	---	13.36	7.97	9.97	0.57	0.70	20	50	47	50	47	---	---
1994	---	14.12	7.24	9.28	0.47	0.59	21	58	52	58	52	---	---
1995	---	16.30	9.70	11.68	0.62	0.82	21	47	46	47	46	---	---
1996	---	19.51	12.37	15.87	0.62	0.81	22	55	55	55	55	---	---
1997	---	18.44	9.26	12.05	0.50	0.67	28	64	59	64	59	---	---
1998	---	23.48	11.45	16.30	0.47	0.70	31	63	59	63	59	---	---
1999	---	22.31	10.38	15.71	0.48	0.72	34	65	64	65	64	---	---
2000	---	21.33	9.84	15.48	0.48	0.76	34	68	67	68	67	---	---
2001	---	23.79	11.02	18.38	0.49	0.90	41	66	66	66	66	---	---
2002	---	22.10	9.02	20.48	0.42	0.89	55	69	63	69	63	---	---
2003	---	17.06	10.56	24.72	0.58	1.43	57	62	69	62	69	---	---
2004	---	24.90	12.69	30.11	0.49	1.18	59	61	56	61	56	---	---
Mean	---	16.55	8.88	13.69	0.56	0.83	30	57	56	57	56	---	---
Median	---	16.68	9.14	11.87	0.52	0.81	22	59	56	59	56	---	---
St Dev	---	5.61	2.28	6.59	0.10	0.21	14	8	8	8	8	---	---
Standard deviations by year													
1987	---	9.27	41.50	68.05	2.64	4.52	12	748	1276	245	436	---	---
1988	---	8.69	16.04	24.78	1.15	1.69	13	231	358	94	149	---	---
1989	---	9.14	23.34	35.39	1.70	2.66	13	439	688	155	253	---	---
1990	---	8.92	15.66	25.59	1.17	1.77	12	263	430	96	157	---	---
1991	---	9.29	16.15	25.54	1.07	1.54	11	248	362	88	135	---	---
1992	---	10.23	11.45	16.37	1.05	1.61	11	243	402	84	141	---	---
1993	---	11.38	13.96	20.87	0.73	1.18	11	138	256	52	97	---	---
1994	---	10.81	11.73	15.28	0.80	1.18	11	180	291	59	97	---	---
1995	---	10.73	18.05	27.82	2.08	3.18	12	764	1151	194	306	---	---
1996	---	13.10	29.35	57.18	1.42	2.62	12	311	614	120	243	---	---
1997	---	13.44	20.83	41.41	1.72	3.47	15	576	1310	151	330	---	---
1998	---	17.09	38.13	93.45	1.41	3.56	16	316	1091	117	338	---	---
1999	---	19.34	50.24	172.3	1.71	7.12	18	449	2571	147	698	---	---
2000	---	21.16	36.51	72.04	1.45	4.54	20	341	1459	116	436	---	---
2001	---	18.79	73.41	331.5	3.07	9.36	19	978	2984	286	922	---	---
2002	---	18.40	29.38	280.1	1.10	7.61	20	266	3222	85	750	---	---
2003	---	16.04	36.86	197.3	1.37	8.01	19	270	2859	108	791	---	---
2004	---	19.39	27.04	86.64	0.75	3.62	19	139	1132	50	349	---	---
Mean	---	13.62	28.31	88.43	1.47	3.85	15	383	1248	125	368	---	---
Median	---	12.24	25.19	49.30	1.41	3.47	13	290	1111	112	318	---	---
St Dev	---	4.39	15.98	94.61	0.63	2.55	3	237	998	64	258	---	---

Table 2.6
Model fit analysis by IBES industry sector

Table 2.6 summaries the relationship between Discounted Cash Flow, *Decision-tree* valuations and market prices as at 30 April of each IBES industry sector. Columns 2-4 of each panel summarise prices, *DCF* valuations and *Decision-tree* valuations. Columns 5-7 summarise the relationship between these valuations, via computations of *DCF* value relative to price (*DCF/P*), *Decision-tree* value relative to price (*DTV/P*) and *Real option%* (1 – *DCF* value/*DTV*). Columns 8-13 present statistics which summarise the variance between model valuations and market prices. For the two valuation methods (*DCF* and *DTV*) I compute the squared percentage error *(SPE)*, the absolute percentage error *(APE)* and the percentage of valuations within 30 percent of the market price. The definitions of these statistics are presented in Sub-section 4.3. Panels A, B and C present the analysis under the assumptions that the competitive advantage period is 10, 20 or 30 years, respectively.

Panel A: Competitive advantage period = 10 years

Industry sector	*N*	*P*	*DCF*	*DTV*	*DCF/P*	*DTV/P*	*RO%*	*SPE*		*APE*		*% in 30% of P*	
								DCF	*DTV*	*DCF*	*DTV*	*DCF*	*DTV*
Pooled summary													
Mean (sum for n)	9427	21.81	14.05	15.99	0.78	0.89	11	103	117	68	71	20	22
Median	---	17.50	8.51	9.57	0.49	0.55	9	60	58	60	58	---	---
St Dev	---	16.90	23.77	28.25	1.01	1.17	9	261	298	77	93	---	---
Means by year													
Basic industries	680	25.36	14.92	16.16	0.76	0.84	7	99	111	61	63	21	24
Capital goods	901	23.17	14.00	15.75	0.77	0.87	10	91	103	64	66	20	22
Consumer durables	514	21.29	18.04	19.50	1.02	1.10	7	124	134	65	68	30	29
Consumer non-dur	868	22.74	13.84	15.00	0.80	0.86	6	98	108	65	67	19	21
Consumer services	1662	19.39	14.02	16.31	0.94	1.08	12	134	153	79	85	19	21
Energy	499	22.99	14.30	18.19	0.71	0.91	19	106	135	75	82	15	17
Finance	1090	26.31	15.19	16.72	0.66	0.72	8	77	81	61	61	19	19
Healthcare	1145	18.41	8.64	11.48	0.57	0.74	21	99	121	78	81	9	12
Technology	1208	17.45	7.79	9.29	0.62	0.73	14	90	102	68	70	16	17
Transport	148	27.53	22.47	23.48	0.87	0.91	4	70	72	55	55	24	24
Utilities	712	25.50	26.42	28.40	1.09	1.17	5	89	102	49	54	49	47
Mean	857	22.74	15.42	17.30	0.80	0.90	10	98	111	65	68	22	23
Med	868	22.99	14.30	16.31	0.79	0.89	8	98	108	65	67	19	21
Std	414	3.32	5.38	5.25	0.17	0.15	6	19	24	9	10	10	9
Medians by year													
Basic industries	---	22.31	12.09	13.07	0.52	0.55	5	54	53	54	53	---	---
Capital goods	---	17.69	9.68	10.70	0.50	0.55	9	59	57	59	57	---	---
Consumer durables	---	18.00	12.89	13.68	0.72	0.77	6	47	45	47	45	---	---
Consumer non-dur	---	19.00	9.66	10.28	0.53	0.56	5	55	54	55	54	---	---
Consumer services	---	14.66	7.78	8.88	0.51	0.57	11	64	62	64	62	---	---
Energy	---	20.56	7.10	8.46	0.37	0.47	18	70	66	70	66	---	---
Finance	---	21.58	8.58	9.31	0.46	0.49	6	59	57	59	57	---	---
Healthcare	---	12.95	4.16	5.38	0.30	0.37	22	75	70	75	70	---	---
Technology	---	12.22	4.56	5.24	0.38	0.45	10	68	65	68	65	---	---
Transport	---	24.22	18.87	19.36	0.60	0.64	4	52	50	52	50	---	---
Utilities	---	23.94	20.28	21.23	0.87	0.89	2	30	32	30	32	---	---
Mean	---	18.83	10.51	11.42	0.52	0.57	9	58	56	58	56	---	---
Med	---	19.00	9.66	10.28	0.52	0.56	6	59	57	59	57	---	---
Std	---	4.19	5.23	5.13	0.16	0.15	6	12	11	12	11	---	---
Standard deviations by year													
Basic industries	---	15.15	11.49	12.69	0.96	1.10	4	265	310	78	91	---	---
Capital goods	---	17.59	14.85	17.37	0.88	1.02	4	202	238	65	79	---	---
Consumer durables	---	15.35	18.90	20.54	1.24	1.34	4	359	384	106	116	---	---
Consumer non-dur	---	15.60	14.48	16.25	0.96	1.07	4	219	250	73	84	---	---
Consumer services	---	16.89	38.96	46.26	1.34	1.53	7	339	383	108	128	---	---
Energy	---	15.36	23.37	31.74	1.02	1.34	9	218	295	75	107	---	---
Finance	---	19.44	23.93	26.28	0.69	0.75	4	150	162	48	53	---	---
Healthcare	---	16.30	19.98	28.57	0.90	1.18	12	195	252	62	90	---	---
Technology	---	17.67	10.72	13.19	0.82	0.98	8	206	245	59	73	---	---
Transport	---	16.27	18.23	19.14	0.69	0.72	2	114	118	45	47	---	---
Utilities	---	12.40	23.70	26.05	0.88	1.00	6	191	221	74	86	---	---
Mean	---	16.18	19.87	23.46	0.94	1.09	6	223	260	72	87	---	---
Med	---	16.27	18.90	20.54	0.92	1.08	4	206	250	73	86	---	---
Std	---	1.80	7.87	9.83	0.20	0.25	3	73	81	20	24	---	---

Panel B: Competitive advantage period = 20 years

Industry sector	*N*	*P*	*DCF*	*DTV*	*DCF/P*	*DTV/P*	*RO%*	*SPE*		*APE*		*% in 30% of P*	
								DCF	*DTV*	*DCF*	*DTV*	*DCF*	*DTV*
Pooled summary													
Mean (sum for n)	9427	21.81	15.06	21.61	0.84	1.22	24	117	190	71	90	21	24
Median	---	17.50	8.96	11.81	0.52	0.67	20	59	56	59	56	---	---
St Dev	---	16.90	27.00	47.82	1.16	1.88	18	320	511	94	167	---	---
Means by year													
Basic industries	680	25.36	15.67	19.12	0.80	1.02	15	105	152	63	73	23	26
Capital goods	901	23.17	15.03	20.56	0.82	1.13	22	99	157	67	81	22	23
Consumer durables	514	21.29	18.94	23.40	1.07	1.32	17	145	181	70	83	30	31
Consumer non-dur	868	22.74	14.56	17.82	0.84	1.04	14	101	136	65	75	22	23
Consumer services	1662	19.39	14.58	22.99	0.99	1.47	27	144	232	81	109	20	23
Energy	499	22.99	16.18	29.60	0.81	1.51	38	134	273	82	121	16	20
Finance	1090	26.31	16.41	20.67	0.73	0.89	15	91	111	65	71	19	20
Healthcare	1145	18.41	9.69	20.86	0.65	1.36	42	118	248	80	116	10	16
Technology	1208	17.45	8.67	13.89	0.70	1.07	31	105	162	71	85	18	23
Transport	148	27.53	23.11	26.52	0.91	1.04	10	80	94	58	64	23	23
Utilities	712	25.50	28.41	34.52	1.16	1.43	12	126	187	56	76	47	45
Mean	857	22.74	16.48	22.72	0.86	1.21	22	114	176	69	87	23	25
Med	868	22.99	15.67	20.86	0.83	1.17	17	105	162	67	81	22	23
Std	414	3.32	5.56	5.73	0.16	0.22	11	22	56	9	19	10	8
Medians by year													
Basic industries	---	22.31	12.31	14.46	0.52	0.63	13	54	51	54	51	---	---
Capital goods	---	17.69	10.01	12.61	0.51	0.65	21	58	55	58	55	---	---
Consumer durables	---	18.00	13.05	15.42	0.72	0.86	15	46	49	46	49	---	---
Consumer non-dur	---	19.00	10.35	11.54	0.54	0.63	12	54	54	54	54	---	---
Consumer services	---	14.66	8.09	11.44	0.54	0.76	26	63	60	63	60	---	---
Energy	---	20.56	7.70	12.71	0.39	0.67	37	70	64	70	64	---	---
Finance	---	21.58	9.11	10.61	0.47	0.55	13	60	57	60	57	---	---
Healthcare	---	12.95	4.77	8.59	0.33	0.55	46	72	65	72	65	---	---
Technology	---	12.22	4.84	7.04	0.42	0.61	24	67	62	67	62	---	---
Transport	---	24.22	18.66	20.07	0.61	0.67	11	53	50	53	50	---	---
Utilities	---	23.94	21.11	23.45	0.87	0.96	7	31	33	31	33	---	---
Mean	---	18.83	10.91	13.45	0.54	0.69	20	57	55	57	55	---	---
Med	---	19.00	10.01	12.61	0.53	0.66	15	58	55	58	55	---	---
Std	---	4.19	5.17	4.80	0.15	0.13	12	12	9	12	9	---	---
Standard deviations by year													
Basic industries	---	15.15	13.32	17.66	1.04	1.52	11	272	419	85	134	---	---
Capital goods	---	17.59	19.05	31.04	0.98	1.57	11	222	386	74	135	---	---
Consumer durables	---	15.35	23.24	30.47	1.45	1.78	8	395	474	126	161	---	---
Consumer non-dur	---	15.60	15.50	20.90	1.00	1.36	10	219	311	78	113	---	---
Consumer services	---	16.89	38.38	68.62	1.44	2.27	15	374	575	119	204	---	---
Energy	---	15.36	34.18	85.62	1.33	2.69	18	348	711	107	245	---	---
Finance	---	19.44	28.98	36.65	0.86	1.11	10	198	248	63	86	---	---
Healthcare	---	16.30	22.93	59.27	1.12	2.45	23	305	576	86	219	---	---
Technology	---	17.67	13.72	26.21	1.00	1.62	16	299	473	77	139	---	---
Transport	---	16.27	19.88	23.57	0.80	0.94	6	150	176	55	69	---	---
Utilities	---	12.40	35.15	46.08	1.26	1.82	12	391	547	114	172	---	---
Mean	---	16.18	24.03	40.55	1.12	1.74	13	288	445	89	152	---	---
Med	---	16.27	22.93	31.04	1.08	1.68	11	299	473	85	139	---	---
Std	---	1.80	8.92	21.93	0.22	0.54	5	84	158	24	55	---	---

Panel C: Competitive advantage period = 30 years

Industry sector	*N*	*P*	*DCF*	*DTV*	*DCF/P*	*DTV/P*	*RO%*	*SPE*		*APE*		*% in 30% of P*	
								DCF	*DTV*	*DCF*	*DTV*	*DCF*	*DTV*
Pooled summary													
Mean (sum for n)	9427	21.81	16.60	34.82	0.94	1.99	36	161	552	79	154	22	24
Median	---	17.50	9.35	15.03	0.54	0.85	32	60	58	60	58	---	---
St Dev	---	16.90	36.19	157.3	1.61	5.43	22	580	2284	93	530	---	---
Means by year													
Basic industries	680	25.36	16.66	25.11	0.85	1.44	25	132	361	68	106	23	26
Capital goods	901	23.17	16.77	30.79	0.90	1.68	34	128	334	74	125	21	23
Consumer durables	514	21.29	20.26	29.61	1.15	1.69	28	184	285	79	113	30	31
Consumer non-dur	868	22.74	15.42	22.44	0.89	1.34	24	115	198	68	95	22	25
Consumer services	1662	19.39	15.40	42.80	1.08	2.40	40	176	793	87	189	22	21
Energy	499	22.99	19.30	56.03	0.98	2.93	51	207	778	96	248	15	20
Finance	1090	26.31	18.07	27.37	0.82	1.19	24	119	189	73	92	18	22
Healthcare	1145	18.41	11.31	45.76	0.80	3.24	57	168	829	89	278	12	19
Technology	1208	17.45	10.29	24.83	0.83	1.85	46	152	409	80	142	18	23
Transport	148	27.53	23.83	31.09	0.96	1.24	19	96	130	64	79	23	21
Utilities	712	25.50	31.55	46.07	1.28	1.98	19	236	571	68	126	46	44
Mean	857	22.74	18.1	34.7	0.96	1.91	33	156	444	77	145	23	25
Med	868	22.99	16.8	30.8	0.93	1.77	28	152	361	74	125	22	23
Std	414	3.32	5.9	11.0	0.15	0.68	13	43	258	10	66	9	7
Medians by year													
Basic industries	---	22.31	12.39	16.53	0.53	0.70	23	55	52	55	52	---	---
Capital goods	---	17.69	10.20	15.34	0.50	0.79	33	59	55	59	55	---	---
Consumer durables	---	18.00	13.03	17.73	0.73	1.00	26	48	51	48	51	---	---
Consumer non-dur	---	19.00	11.05	13.87	0.55	0.73	22	54	53	54	53	---	---
Consumer services	---	14.66	8.59	15.07	0.58	1.03	41	62	63	62	63	---	---
Energy	---	20.56	8.28	20.12	0.40	0.97	53	70	72	70	72	---	---
Finance	---	21.58	9.21	12.21	0.49	0.65	22	61	59	61	59	---	---
Healthcare	---	12.95	5.39	14.02	0.36	0.89	65	71	66	71	66	---	---
Technology	---	12.22	5.21	10.11	0.44	0.84	40	67	62	67	62	---	---
Transport	---	24.22	18.67	21.34	0.59	0.73	21	54	50	54	50	---	---
Utilities	---	23.94	21.34	26.02	0.88	1.04	14	32	35	32	35	---	---
Mean	---	18.83	11.22	16.58	0.55	0.85	33	57	56	57	56	---	---
Med	---	19.00	10.20	15.34	0.54	0.85	26	59	55	59	55	---	---
Std	---	4.19	5.03	4.52	0.15	0.14	16	11	10	11	10	---	---
Standard deviations by year													
Basic industries	---	15.15	17.56	39.63	1.31	3.59	15	373	1254	113	345	---	---
Capital goods	---	17.59	29.03	76.91	1.28	3.27	16	294	885	104	310	---	---
Consumer durables	---	15.35	33.55	54.13	1.84	2.77	12	503	779	167	262	---	---
Consumer non-dur	---	15.60	18.06	30.35	1.14	1.96	15	260	454	92	174	---	---
Consumer services	---	16.89	38.41	283.8	1.76	7.81	19	564	3270	153	770	---	---
Energy	---	15.36	58.39	287.3	2.08	7.54	22	624	2359	184	738	---	---
Finance	---	19.44	36.93	58.72	1.17	1.88	15	293	481	94	165	---	---
Healthcare	---	16.30	27.81	145.8	1.67	7.98	27	522	2186	143	781	---	---
Technology	---	17.67	26.50	98.01	1.51	4.00	18	485	1400	129	384	---	---
Transport	---	16.27	22.24	30.76	0.96	1.28	9	212	278	72	104	---	---
Utilities	---	12.40	62.91	110.8	2.34	5.63	16	959	2215	226	558	---	---
Mean	---	16.18	33.76	110.6	1.55	4.34	17	463	1415	134	417	---	---
Med	---	16.27	29.03	76.91	1.53	3.80	16	485	1254	129	345	---	---
Std	---	1.80	14.97	93.54	0.43	2.50	5	214	968	46	253	---	---

Table 2.7
Model fit analysis for Technology and Healthcare sectors

Table 2.7 summarises the relationship between Discounted Cash Flow valuations, *Decision-tree* valuations and market prices as at 30 April of each year, for the Technology and Healthcare sectors, and under the assumption that the Competitive Advantage Period is either 10, 20 or 30 years. Columns 3-5 present the mean *Real option%* (1 – *DCF* value/*Decision-tree* value); columns 6-11 present the square root of the mean squared percentage error, where percentage error = Value/Price-1; columns 12-17 present the median absolute percentage deviation; and columns 18-23 present the percentage of valuations which are within 30 percent of the market price.

	N	*Mean real option %*			*Square root of the mean squared perc error*						*Median absolute percentage deviation*						*% of valuations within 30% of price*					
					DCF			*DTV*			*DCF*			*DTV*			*DCF*			*DTV*		
CAP (yrs)		*10*	*20*	*30*	*10*	*20*	*30*	*10*	*20*	*30*	*10*	*20*	*30*	*10*	*20*	*30*	*10*	*20*	*30*	*10*	*20*	*30*
Pooled	9427	11	24	36	103	117	161	117	190	552	60	59	60	58	56	58	20	21	22	22	24	24
Tech	1208	14	31	46	90	105	152	102	162	409	68	67	67	65	62	62	16	18	18	17	23	23
Healthcare	1145	21	42	57	99	118	168	121	248	829	75	72	71	70	65	66	9	10	12	12	16	19
Technology																						
1987	26	4	10	21	75	87	111	76	94	147	70	67	72	69	70	75	0	8	4	0	12	15
1988	27	7	17	30	66	77	102	66	90	154	50	44	45	45	32	47	19	33	37	22	44	33
1989	29	7	17	30	69	124	279	74	168	464	49	43	41	44	34	42	31	38	31	34	41	41
1990	33	7	18	32	60	98	199	63	128	343	40	58	51	41	55	54	33	33	33	36	27	27
1991	36	8	18	32	59	83	154	59	101	235	51	53	54	49	49	53	31	31	28	31	33	31
1992	42	8	19	33	58	79	176	58	98	298	52	52	48	48	42	42	21	24	14	26	38	38
1993	42	8	19	32	59	55	59	59	56	83	56	50	53	52	50	47	17	19	31	17	33	31
1994	44	7	19	32	68	71	85	68	79	128	65	61	63	64	53	57	11	23	16	14	34	32
1995	49	7	18	31	59	63	112	58	73	214	59	58	55	56	53	49	24	24	24	20	22	22
1996	54	7	19	32	73	80	111	74	95	192	62	57	54	61	58	61	17	28	30	22	28	26
1997	77	8	20	34	86	89	97	90	105	139	69	70	67	69	63	55	9	12	14	10	18	22
1998	86	9	22	37	91	89	90	97	108	138	72	70	68	69	65	63	13	13	16	12	19	19
1999	91	10	23	38	117	119	132	128	151	227	72	68	67	72	63	57	14	13	15	12	20	25
2000	98	10	25	41	91	100	125	96	128	239	83	83	81	81	79	74	12	13	8	9	11	15
2001	101	14	33	50	143	202	335	163	322	943	72	72	70	73	65	63	12	13	14	17	23	20
2002	110	22	47	65	80	83	90	90	129	237	69	71	73	63	60	69	16	13	14	16	18	21
2003	132	27	53	71	101	108	130	137	238	636	66	66	68	69	71	77	20	21	18	18	22	15
2004	131	25	53	71	75	76	80	85	147	363	72	71	71	71	59	64	14	15	17	19	18	24
Healthcare																						
1987	21	4	9	17	228	400	740	245	495	1314	65	64	61	64	62	61	0	5	5	0	10	5
1988	24	5	12	20	76	79	83	79	89	110	55	51	50	53	50	46	17	17	13	17	21	38
1989	23	5	10	19	115	145	187	122	190	306	59	52	49	56	42	49	17	26	35	17	35	26
1990	24	5	11	19	68	72	76	69	80	101	63	61	54	63	56	49	13	8	8	17	8	29
1991	23	5	11	19	72	76	84	74	88	116	71	68	63	70	68	63	0	4	4	4	9	9
1992	27	5	9	17	106	132	184	113	156	287	72	69	64	71	69	63	7	4	4	7	4	11
1993	28	6	12	22	71	82	128	74	103	221	59	56	51	57	58	52	11	11	18	14	21	25
1994	30	7	14	23	68	67	72	66	66	86	66	65	66	64	61	56	7	10	10	10	10	13
1995	33	8	18	29	99	90	83	104	110	145	68	61	61	65	62	60	9	15	12	12	21	15
1996	36	9	19	31	81	109	207	91	185	530	73	70	75	71	71	71	17	6	0	8	3	11
1997	65	10	23	36	68	67	66	68	72	122	71	72	70	72	69	64	14	11	15	15	9	11
1998	79	17	36	53	130	158	218	163	300	765	77	75	73	74	70	66	13	19	14	16	11	11
1999	89	19	38	55	113	118	151	137	304	1364	73	73	72	69	70	71	11	13	13	11	16	17
2000	104	24	49	66	96	90	95	114	177	756	78	77	75	76	68	76	11	13	13	13	19	14
2001	109	24	49	66	87	104	161	100	209	929	82	79	77	79	71	66	4	3	6	5	17	23
2002	132	32	61	78	98	113	149	130	293	1053	82	78	78	73	67	67	6	8	13	11	17	23
2003	146	35	64	80	105	114	134	156	385	1006	76	75	71	70	64	97	10	12	14	15	17	18
2004	152	31	61	78	80	79	81	90	170	690	77	75	75	71	60	64	7	9	10	10	22	24

5 Results

In this section, I evaluate the performance of investment portfolios formed on the basis of value relative to price, where value is estimated according to the *DCF* and *Decision-tree* valuation methods. The two research questions are (1) whether fundamental valuation techniques can be used to identify mispriced securities, making them useful for portfolio formation; and (2) whether incorporating the volatility of revenue growth into equity valuation, via *Decision-tree* valuation, results in additional outperformance. Hence, an appropriate research method is the evaluation of portfolio performance.

The results support the contention that fundamental equity analysis is useful in portfolio formation, and the magnitude of outperformance (close to 7 percent a year) is material to a portfolio manager. An additional advantage of this approach is that it allows me to assess the probability of reduced investment performance over a typical three-year investment horizon. I perform this analysis by re-sampling excess portfolio returns, under the assumption that returns are uncorrelated over time. Underperformance during years in which growth stocks outperformed means that there is a 20-30 percent probability that portfolio performance would have deteriorated by trading on the basis of value/price.

With regard to this second research question, the uncertainty associated with additional parameter estimates - which increases with the assumed competitive advantage period – means that any information content associated with the *Decision-tree* valuation model could be outweighed by this additional noise. If the *Decision-tree* valuation model provides superior information on fundamental values, relative to the *DCF* model, its application should result in better investment performance. In contrast, if the *Decision-tree* valuation model simply introduces noise, we should observe worse investment performance.

I test this prediction by forming equally-weighted long-short portfolios each year, and determining whether mean returns are significantly different from zero. The advantage of the long-short portfolio evaluation technique is that sample firms are effectively being used as their own benchmark. I perform this test before and after controlling for factors shown to explain a substantial proportion of the variation in stock returns – size, the book-to-market equity ratio, and market returns (Fama and French, 1992, 1993), as well as momentum (Carhart, 1997).

If portfolios formed on the basis of *DCF* or *Decision-tree* valuations achieve significant outperformance, this provides support for the fundamental investment analysis typically performed by equity analysts and investors. In addition, if portfolios formed on the basis of

Decision-tree valuations outperform portfolios formed on the basis of *DCF* valuations, this provides support for incorporating the volatility of revenue growth into equity analysis.

I analyse monthly portfolio returns over holding periods of up to one year. There is no theoretical basis for arguing that a 12-month holding period will be sufficient to detect outperformance. However, the premise of fundamental valuation is that if market prices diverge from fundamental value they will revert to their intrinsic value at some (unspecified) time. This is likely to occur in response to information that resolves uncertainty, such as an earnings release. A 12-month period in which to detect outperformance appears reasonable, considering the investment horizons of active portfolio managers.

The concern remains, though, as to why market prices should diverge from intrinsic value in the first place. In other words, what is the basis for the presumption that sample firms are mispriced? To address this concern, consider the parameters which underlie the models used to estimate intrinsic values for sample stocks. As much as possible, parameters underlying the model valuations are objectively determined, with other estimates - relating to growth and the competitive advantage period - being derived from market prices. Therefore, we should expect model prices to diverge from market prices. This divergence could happen for three reasons. First, the models are mis-specified, and are therefore not the appropriate way to determine intrinsic value; second, the parameters underlying the models are subject to estimation error; and third, market prices differ from intrinsic value. The first two reasons for divergence imply that noise and/or bias is incorporated into model prices. The third reason would imply outperformance from model portfolios, as explained below.

As a base case, assume that market prices fully reflect available information (that is, they are "correct") and consider long-short portfolios of sample stocks formed through random selection. These should achieve risk-adjusted returns insignificantly different from zero. Portfolios formed using noisy estimates of intrinsic value should fare no better, because this also amounts to a random selection. If intrinsic values are biased in some way, such as high-beta stocks in the long portfolio and low-beta stocks in the short portfolio, the portfolio return should be no different from zero, after controlling for factors shown to explain stock returns. Finally, if market prices are correct, then the third reason for divergence does not apply, so our prior expectation is that returns should be insignificantly different from zero.

Now, consider the case where we assume that market prices are not correct. If we assume that, at some stage, prices will move closer to their intrinsic value we should expect abnormal returns over some holding period, so long as this is not outweighed by noise underlying the estimates of intrinsic value. So the issue is not whether we should expect abnormal returns; the issues are (1) whether the holding period will be long enough to detect outperformance; and (2) whether any actual outperformance remains undetected because of noise underlying the estimates of intrinsic value.

I measure portfolio performance using monthly returns and annual returns. Given that the period under study is only 18 years, evaluating monthly returns increases the power of significance tests due to the increase in the number of observations to 216. It also allows me to assess the volatility of monthly returns, to better assess whether any outperformance is associated with increased risk. However, all portfolios are formed using share price and accounting information as a 30 April of each year, which was selected as the date most likely to contain up-to-date earnings forecasts for the majority of the sample. The majority of companies report on a calendar-year basis, following which analysts typically update their earnings forecasts in the IBES database. Allowing a four-month lag between the calendar-year end and portfolio formation means that the earnings forecasts relied upon are likely to incorporate recent annual report data.

I form three sets of equally-weighted long-short portfolios on the basis of value (*DCF* or *Decision-tree*) relative to price, where the long and short components each comprise 10 percent, 20 percent or 30 percent of stocks in each year. The use of alternative portfolio partitions – deciles, quintiles or the 30/40/30 split – is to examine the sensitivity of portfolio performance to selecting stocks with extremely low or high prices. For the full sample this is not a great concern, as the least diversified portfolio contained 54 stocks. But for sub-samples formed on the basis of size and the market-to-book ratio, the number of stocks in each decile is a quarter of this range. The portfolio with the largest number of stocks (565) is that comprising the top and bottom 30 percent of stocks, formed in 2003.

Stock returns are computed on a continuously-compounded basis and include the reinvestment of dividends. When testing whether the mean returns to long-short portfolios are significantly different from zero, I perform one-sample t-tests. When comparing performance between portfolios, I perform matched-pairs t-tests. I compare the volatility of portfolio returns using F-tests. All p-values refer to two-tailed significance tests.

For the full sample, long-short portfolios of the top and bottom deciles of stocks had average monthly returns of close to 0.6 percent, which was significant at the 5 percent level, regardless of whether *DCF* or *Decision-tree* valuations were performed and the assumed competitive advantage period. Mean annual returns were around 7 percent, but were only significant at the 10 percent level when a competitive advantage period of 30 years was assumed. Monthly excess returns after controlling for factors which explain stock returns ranged from 0.4-0.6 percent, depending on the assumed competitive advantage period, while annual returns ranged from 6-8 percent. In most cases, results were significant at the 5 percent level.

When the sample was partitioned into four sub-samples on the basis of size and the market-to-book ratio, the portfolios drawn from the set of small, high market-to-book stocks achieved the most consistent excess returns. This was also the case for the sub-sample of growth stocks, where these were defined as those in the Technology, Healthcare and Consumer Services industries.

In sum, there is evidence that fundamental valuation techniques are useful in achieving superior risk-adjusted performance, provided they incorporate assumptions regarding revenue growth and margins which are consistent with normal long-term returns on investment.

5.1 Mean returns and volatility of investment portfolios

In this section, I analyse the raw returns performance of long-short investment portfolios. This analysis is separated into sub-sections relating to the full sample, four sub-samples formed on the basis of size and market-to-book equity and two samples formed on industry growth characteristics.

5.1.1 Full sample

A number of important points emerge from analysis of investment performance. First, portfolios of stocks ranked in the top decile on the basis of value relative to price earned higher average returns than stocks ranked in the bottom decile. Second, as stocks are partitioned into extreme deciles, the volatility of returns increases. My explanation for this is that volatile stocks are more likely to have equity prices which deviate from a theoretical value estimated from inputs obtained from publicly available information. Regardless of the reason for this volatility, controlling for portfolio risk is paramount. However, the third important result is that, even after controlling for the volatility of returns, there is evidence that investment portfolios formed using fundamental valuations achieve superior performance. Finally, there is marginal difference in portfolio performance, regardless of whether *Decision-tree* or *DCF* valuations are used, or the assumed competitive advantage period. This occurs because 60 percent of stocks are ranked in the same decile, regardless of the valuation technique used.

Figure 2.6 illustrates the mean annual stock returns over 18 years for each decile, assuming a competitive advantage period of 30 years. For portfolios formed using *Decision-tree* valuations the mean annual return for decile 1 stocks was 15.4 percent, compared to 7.6 percent for the mean for decile 10, a difference which was significant at the 10 percent level. A similar result holds for portfolios formed according to *DCF* valuations, with the mean annual return declining from 15.1 percent to 7.6 percent, which had comparable significance. Hence, there is preliminary evidence that fundamental equity valuation has potential to result in outperformance. While the difference in returns is significant only for the top and bottom deciles of stocks, long-short portfolios formed on this basis contained between 54 and 188 stocks, depending on the year in question.

Further, the magnitude of the difference in returns is economically meaningful, even if a portfolio manager is required to form a well-diversified, long-only portfolio. Say a naïve investment manager formed an equally-weighted portfolio of all stocks in each year, and so earned the average return of 11.49 percent over the sample period. Now say that an additional 10 percent of the portfolio is allocated to decile 1 stocks, and no investment is made in decile 10 stocks. Annual returns in this instance would have risen by 0.75 percent a year, which is economically significant, especially when we consider that the portfolio is only subject to annual re-balancing, so incremental transaction costs are minimal.

Figure 2.6

Mean annual returns for the full sample according to deciles formed on the basis of value/price assuming a competitive advantage period of 30 years

Figure 2.6 presents mean annual returns to decile portfolios of US stocks ranked according to the ratio of value/price, where value is estimated using the *Discounted Cash Flow* and *Decision-tree* valuation models, and assuming a competitive advantage period of 10, 20 or 30 years. The valuations refer to 9427 firm-years from 1987-2004 and are performed using information available at 30 April of each year. The subsequent returns are computed as *ln* (P_t/P_0) where P_t = an estimate of price in *t* months that includes reinvestment of any dividends; and P_0 is the share price as at 30 April.

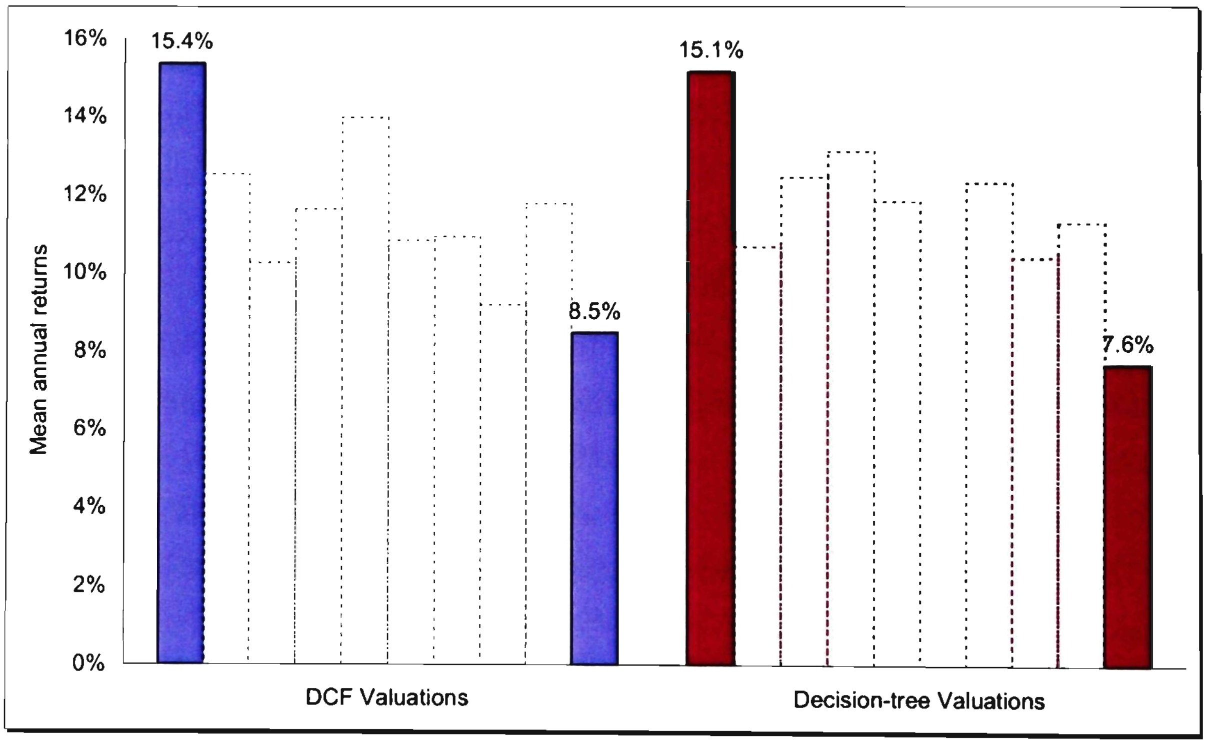


Table 2.8 summarises the mean returns earned by portfolios according to deciles, as well as the performance of long-short portfolios formed in three ways – according to the top and bottom deciles, the top and bottom quintiles, and a 30/40/30 split. On the left-hand side, I present the mean returns for each partition, while tests for differences amongst partitions appear on the right-hand side. Each row of the table refers to portfolios formed after assuming a competitive advantage period of 10, 20 or 30 years. For example, the data appearing in the figure above is drawn from the top left section of Panel B, in the rows labelled "30".

Table 2.8

Returns to portfolios formed on the basis of value relative to price

Table 2.8 presents returns to portfolios of US stocks ranked according to the ratio of value/price, where value is estimated using the *Discounted Cash Flow* and *Decision-tree* valuation models, and assuming a competitive advantage period of 10, 20 or 30 years. The valuations refer to 9427 firm-years from 1987-2004 and are performed using information available at 30 April of each year. The subsequent returns are computed as $ln\ (P_t/P_0)$ where P_t = an estimate of price in t months that includes reinvestment of any dividends; and P_0 is the share price as at 30 April. Panel A refers to monthly returns and panel B refers to cumulative returns over a 12-month holding period, where the portfolios are not rebalanced. The left-hand side of each panel presents the mean returns to portfolios formed on the basis of deciles, quintiles and by selecting the lower 30 percent, middle 40 percent and upper 30 percent of stocks according to value/price. The right-hand side of each panel presents the difference in means and the p-values from the matched pairs t-test.

Panel A: Full sample; Monthly returns

		Mean returns										Difference in mean returns and p-values for t-tests							
Decile		1	2	3	4	5	6	7	8	9	10	1 v 10		2 v 10		1 v 9		2 v 9	
DCF	10	1.22	1.11	0.99	0.99	1.01	0.88	0.91	0.90	0.94	0.63	0.59	**(0.05)**	0.47	**(0.09)**	0.29	(0.22)	0.17	(0.41)
	20	1.23	1.09	0.94	1.03	1.05	0.86	0.97	0.81	0.93	0.68	0.55	**(0.05)**	0.41	(0.14)	0.31	(0.17)	0.16	(0.41)
	30	1.28	1.04	0.85	0.97	1.16	0.90	0.91	0.77	0.98	0.70	0.58	**(0.03)**	0.34	(0.18)	0.30	(0.16)	0.06	(0.75)
DTV	10	1.24	1.10	0.97	1.01	1.04	0.83	0.93	0.89	0.90	0.67	0.57	**(0.05)**	0.43	(0.12)	0.34	(0.14)	0.20	(0.34)
	20	1.23	1.05	0.94	1.00	1.10	0.98	0.90	0.78	0.97	0.64	0.59	**(0.03)**	0.42	(0.10)	0.26	(0.24)	0.09	(0.64)
	30	1.26	0.89	1.04	1.09	0.99	0.84	1.03	0.87	0.94	0.64	0.63	**(0.02)**	0.25	(0.26)	0.32	(0.16)	-0.05	(0.80)
Quintile		1	2	3	4	5						1 v 5		2 v 5		1 v 4		2 v 4	
DCF	10	1.16	0.99	0.94	0.91	0.79						0.38	**(0.10)**	0.21	(0.30)	0.26	(0.12)	0.09	(0.49)
	20	1.16	0.98	0.95	0.89	0.80						0.36	(0.10)	0.18	(0.32)	0.27	(0.10)	0.09	(0.41)
	30	1.16	0.91	1.03	0.84	0.84						0.32	(0.11)	0.07	(0.71)	0.32	**(0.05)**	0.07	(0.53)
DTV	10	1.17	0.99	0.93	0.91	0.79						0.38	**(0.09)**	0.21	(0.29)	0.26	(0.12)	0.08	(0.55)
	20	1.14	0.97	1.04	0.84	0.80						0.34	**(0.09)**	0.17	(0.32)	0.30	**(0.06)**	0.14	(0.26)
	30	1.08	1.07	0.91	0.95	0.79						0.29	(0.14)	0.28	**(0.08)**	0.13	(0.42)	0.12	(0.28)
		Top 30%	Middle 40%	Bottom 30%								1 v 3		2 v 3		1 v 2			
DCF	10	1.11	0.95	0.83								0.28	(0.13)	0.12	(0.39)	0.16	(0.13)		
	20	1.09	0.98	0.80								0.28	(0.11)	0.17	(0.21)	0.11	(0.30)		
	30	1.06	0.99	0.82								0.24	(0.14)	0.17	(0.20)	0.07	(0.51)		
DTV	10	1.10	0.95	0.82								0.28	(0.12)	0.13	(0.34)	0.15	(0.15)		
	20	1.07	0.99	0.79								0.28	**(0.09)**	0.20	**(0.10)**	0.08	(0.47)		
	30	1.06	0.99	0.81								0.25	(0.11)	0.17	(0.12)	0.08	(0.49)		

Panel B: Annual returns

		Mean returns										Difference in mean returns and *p*-values for *t*-tests							
Decile		1	2	3	4	5	6	7	8	9	10	1 v 10		2 v 10		1 v 9		2 v 9	
DCF	10	14.7	13.3	11.9	11.9	12.1	10.5	10.9	10.9	11.2	7.6	7.0	(0.16)	5.7	(0.23)	3.4	(0.37)	2.0	(0.54)
	20	14.8	13.1	11.3	12.3	12.6	10.3	11.6	9.7	11.1	8.2	6.6	(0.14)	4.9	(0.28)	3.7	(0.32)	2.0	(0.57)
	30	15.4	12.5	10.3	11.6	14.0	10.8	10.9	9.2	11.8	8.5	6.9	**(0.08)**	4.1	(0.30)	3.6	(0.27)	0.7	(0.82)
DTV	10	14.9	13.2	11.6	12.1	12.4	9.9	11.2	10.7	10.8	8.1	6.8	(0.16)	5.1	(0.26)	4.1	(0.33)	2.4	(0.51)
	20	14.7	12.7	11.3	12.1	13.2	11.7	10.7	9.4	11.6	7.6	7.1	(0.12)	5.0	(0.26)	3.1	(0.42)	1.1	(0.73)
	30	15.1	10.7	12.5	13.1	11.8	10.1	12.3	10.4	11.3	7.6	7.5	**(0.08)**	3.0	(0.39)	3.9	(0.32)	-0.6	(0.81)
Quintile		1	2	3	4	5						1 v 5		2 v 5		1 v 4		2 v 4	
DCF	10	14.0	11.9	11.3	10.9	9.4						4.5	(0.26)	2.5	(0.45)	3.1	(0.32)	1.1	(0.58)
	20	13.9	11.8	11.4	10.7	9.6						4.3	(0.26)	2.2	(0.44)	3.2	(0.29)	1.1	(0.52)
	30	14.0	10.9	12.4	10.1	10.1						3.8	(0.24)	0.8	(0.75)	3.9	(0.16)	0.9	(0.62)
DTV	10	14.0	11.9	11.2	11.0	9.4						4.6	(0.26)	2.5	(0.43)	3.1	(0.34)	0.9	(0.63)
	20	13.7	11.7	12.4	10.1	9.6						4.1	(0.26)	2.0	(0.44)	3.7	(0.23)	1.6	(0.37)
	30	12.9	12.8	11.0	11.3	9.5						3.5	(0.28)	3.3	(0.11)	1.6	(0.56)	1.4	(0.36)
		Top 30%	Middle 40%	Bottom 30%								1 v 3		2 v 3		1 v 2			
DCF	10	13.3	11.3	9.9								3.4	(0.34)	1.4	(0.49)	2.0	(0.32)		
	20	13.1	11.7	9.7								3.4	(0.30)	2.0	(0.25)	1.4	(0.48)		
	30	12.7	11.8	9.8								2.9	(0.30)	2.0	(0.22)	0.9	(0.60)		
DTV	10	13.2	11.4	9.9								3.4	(0.34)	1.6	(0.47)	1.8	(0.31)		
	20	12.9	11.9	9.5								3.4	(0.28)	2.4	(0.11)	1.0	(0.61)		
	30	12.8	11.8	9.8								3.0	(0.27)	2.1	(0.13)	0.9	(0.59)		

Table 2.8 shows that the positive returns to long-short portfolios formed from the top and bottom deciles was consistent, regardless of the competitive advantage period assumed or the valuation technique. Monthly returns were typically 0.6 percent (with *p*-values of 2 – 5 percent), which corresponded to annual returns of 6.6 – 7.5 percent. There is a positive association between returns and the assumed competitive advantage period, and the annual returns are significant at the 10 percent level only when *CAP* = 30 years. However, the difference in mean estimates for the different valuation methods and *CAP* assumptions is not significant. The mean returns to long-short quintile portfolios are 0.3 – 0.4 percent per month, which corresponds to 3.5 – 4.5 percent a year, and monthly returns have *p*-values of 9-14 percent.

Analysis of the variability of portfolio returns suggests that portfolios of stocks selected as most over- or under-valued, are also the most volatile. Figure 2.7 illustrates the standard deviation of annual and monthly returns to each decile portfolio, assuming *CAP* = 30 years, which appear in Table 2.9. In addition, Table 2.9 presents the results of the full set of significance tests which compare the standard deviation of the decile portfolios, assuming *CAP* = 30 years. In each case, comparisons with the minimum variance portfolio are highlighted.

In reference to the annual returns to stocks allocated to deciles according to *Decision-tree* value/price, the decile 1 portfolio is significantly more volatile than the portfolios formed from deciles 7-9 (*p*-values from 1-6 percent). But the decile 10 portfolio is significantly more volatile than the decile 9 portfolio. For the portfolios formed from *DCF* valuations, there are no significant differences in the volatility of annual returns.

However, when we consider the volatility of monthly returns, we observe this pattern of increased volatility at the extreme deciles, regardless of the valuation method selected. For *DCF* portfolios, the standard deviation of monthly returns to the portfolio of stocks in decile 10 is 0.8 percent greater than the standard deviation of returns to the decile 1 portfolio (*p*-value = 0.06). The portfolio of stocks in decile 4 has the lowest standard deviation at 4.4 percent, which is significantly different from all portfolios except deciles 3-6. For *Decision-tree* portfolios, the minimum variance portfolio is decile 5, which has a standard deviation of 4.6 percent. This is significantly lower than the volatility of returns to portfolios 1-2 and 9-10.

Figure 2.7
Standard deviation of returns to portfolios from the decile rankings of stocks according to value relative to price assuming a competitive advantage period of 30 years

Figure 2.7 presents the standard deviation of 18 annual returns and 216 monthly returns to decile portfolios of US stocks ranked according to the ratio of value/price, where value is estimated using the *Discounted Cash Flow* and *Decision-tree* valuation models, and assuming a competitive advantage period of 10, 20 or 30 years. The valuations refer to 9427 firm-years from 1987-2004 and are performed using information available at 30 April of each year. The subsequent returns are computed as $ln\ (P_t/P_0)$ where P_t = an estimate of price in t months that includes reinvestment of any dividends; and P_0 is the share price as at 30 April.

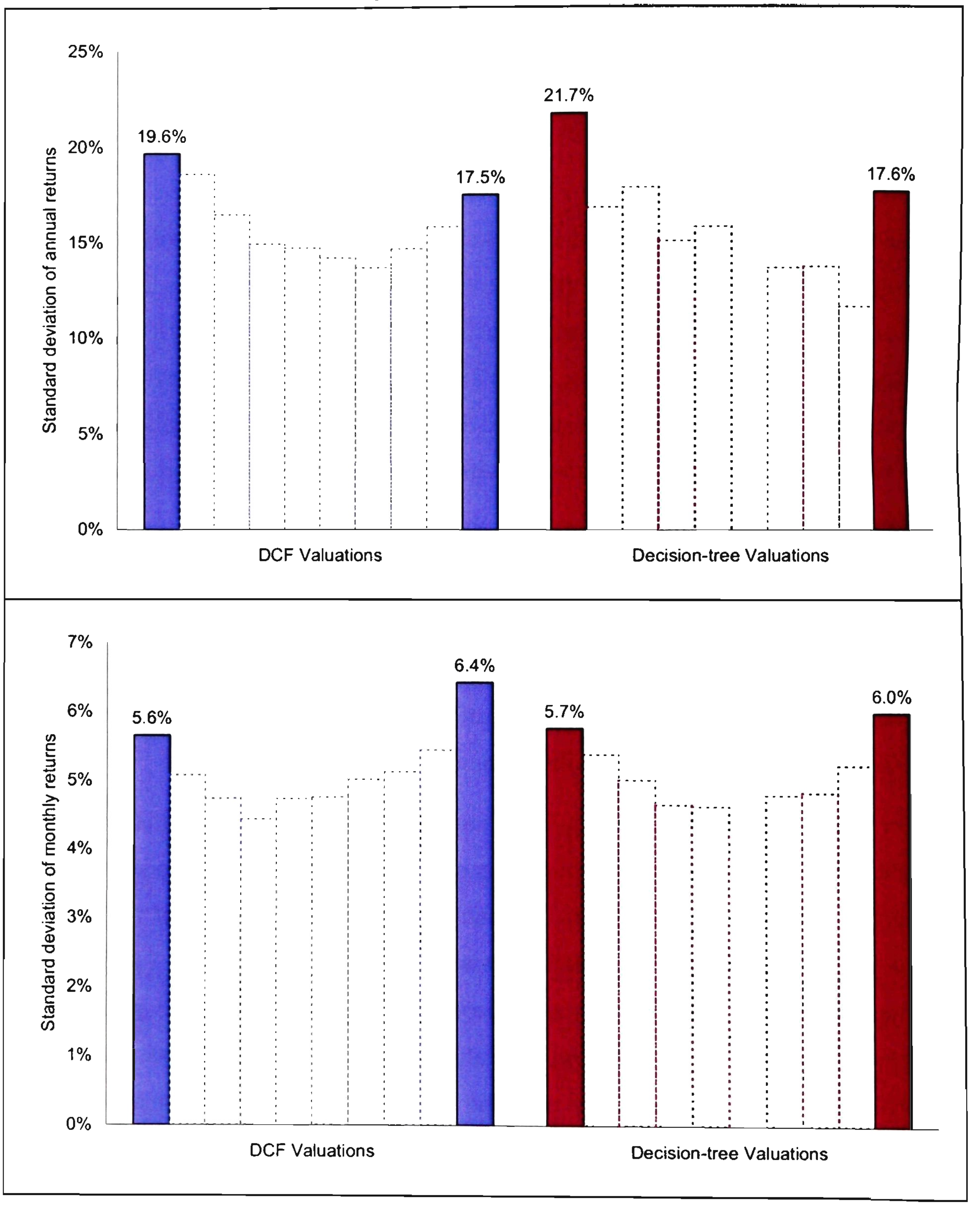


Table 2.9
Comparison of returns volatility

Table 2.9 presents the results of *F*-tests for significant differences in the variance of returns to portfolios formed on the basis of value/price. The upper section of each panel refers to portfolios formed on the basis of *DCF* valuations, while the lower section of each panel refers to *Decision-tree* portfolios. Each section presents the standard deviation of returns to each decile and the two-tailed significance level associated with the ratio of variances. Panel A presents data on 18 cumulative annual returns and Panel B presents data on 216 monthly returns. In each case, comparisons with the minimum variance portfolio are highlighted.

Panel A: Annual returns

Decile	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
St Dev	**19.6**	**18.6**	**16.5**	**14.9**	**14.7**	**14.2**	**13.7**	**14.7**	**15.8**	**17.5**
***DCF* valuation Significance levels for *F*-tests of difference in variance**										
1		0.82	0.47	0.27	0.25	0.19	0.15	0.24	0.38	0.64
2			0.63	0.38	0.35	0.28	0.22	0.34	0.52	0.81
3				0.69	0.65	0.55	0.46	0.64	0.87	0.81
4					0.96	0.84	0.73	0.94	0.82	0.52
5						0.88	0.77	0.99	0.77	0.49
6							0.88	0.90	0.66	0.40
7								0.78	0.56	0.32
8									0.76	0.48
9										0.68

Decile	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
St Dev	**21.7**	**16.8**	**17.8**	**15.1**	**15.8**	**15.4**	**13.6**	**13.7**	**11.6**	**17.6**
***Decision-tree* valuation - Significance levels for *F*-tests of difference in variance**										
1		0.30	0.43	0.14	0.20	0.17	**0.06**	**0.06**	**0.01**	0.39
2			0.81	0.65	0.80	0.72	0.39	0.40	0.14	0.85
3				0.49	0.62	0.55	0.27	0.28	**0.08**	0.95
4					0.85	0.93	0.68	0.69	0.29	0.53
5						0.92	0.55	0.56	0.22	0.66
6							0.62	0.63	0.25	0.59
7								0.99	0.52	0.30
8									0.51	0.31
9										**0.10**

Panel B: Monthly returns

Decile	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
St Dev	**5.65**	**5.07**	**4.73**	**4.43**	**4.72**	**4.75**	**5.00**	**5.12**	**5.43**	**6.41**
***DCF* valuation - Significance levels for *F*-tests of difference in variance**										
1		0.11	**0.01**	**0.00**	**0.01**	**0.01**	**0.08**	0.15	0.57	**0.06**
2			0.31	**0.05**	0.30	0.34	0.85	0.89	0.31	**0.00**
3				0.34	0.98	0.95	0.41	0.25	**0.04**	**0.00**
4					0.35	0.31	**0.07**	**0.04**	**0.00**	**0.00**
5						0.93	0.40	0.24	**0.04**	**0.00**
6							0.44	0.28	**0.05**	**0.00**
7								0.74	0.23	**0.00**
8									0.38	**0.00**
9										**0.02**

Decile	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
St Dev	**5.75**	**5.37**	**5.00**	**4.64**	**4.62**	**5.02**	**4.78**	**4.82**	**5.21**	**5.97**
***Decision-tree* valuation - Significance levels for *F*-tests of difference in variance**										
1		0.32	**0.04**	**0.00**	**0.00**	**0.05**	**0.01**	**0.01**	0.15	0.58
2			0.30	**0.03**	**0.03**	0.33	**0.09**	0.11	0.66	0.12
3				0.27	0.24	0.95	0.51	0.58	0.55	**0.01**
4					0.94	0.24	0.66	0.58	**0.09**	**0.00**
5						0.21	0.60	0.53	**0.08**	**0.00**
6							0.47	0.54	0.60	**0.01**
7								0.91	0.21	**0.00**
8									0.25	**0.00**
9										**0.05**

To this point, two conclusions can be reached. First, there is evidence that fundamental analysis which incorporates mean-reversion of revenue growth is associated with increased equity returns. Incorporating the volatility of revenue growth into valuations, via *Decision-tree* analysis, results in mean estimates of value which are closer to market price. But this does not result in a significant change in investment performance.

Second, there is evidence that stocks selected as most over- or under-valued by these valuation techniques are the most volatile stocks. This is likely to occur because the valuations are performed using data which, by construction, is less timely and less volatile than equity prices. The individual earnings forecasts which comprise consensus estimates enter the IBES database over a period of time, with each analyst updating their forecast at differing intervals. So the consensus earnings forecast places equal weight on each estimate, regardless of its timeliness. The resulting consensus forecast will be significantly smoother than equity prices, which react to new information instantaneously. Hence, when valuations are performed using consensus earnings forecasts, the most volatile stocks are most likely to be identified as the most over- or under-valued.

I assessed the impact of risk variation in the investment portfolios in two ways. First, I computed a Sharpe ratio for each decile portfolio in each year, according to the following equation:

$$Sharpe = \frac{r_{port} - r_f}{\sigma_{port}} \tag{2.66}$$

where:

r_{port} = the continuously-compounded annual return on the portfolio;

r_f = the continuously-compounded yield on 10-year Treasury bonds at the start of the year; and

σ_{port} = the annualised standard deviation of the portfolio returns over 12 months.

Sharpe ratios for each decile portfolio in each year are presented in Table 2.10, along with raw returns.

Second, for long-short portfolios formed on the basis of the top and bottom deciles of stocks ranked according to value/price, I computed the information ratio. The information ratio is the ratio of excess portfolio returns relative to the standard deviation of portfolio returns, as presented below. For long-short portfolios the benchmark return is zero, so the information ratio becomes the ratio of returns to the standard deviation of those returns.

$$Information\ ratio = \frac{r_{long} - r_{short}}{\sigma_{ER}} \tag{2.67}$$

where:

r_{long} - r_{short} = the continuously-compounded annual return on a long-short investment portfolio formed on the basis of the top and bottom decile of stocks ranked according to value/price;

σ_{ER} = the annualised standard deviation of monthly returns on the long-short portfolio.

The information ratio is a measure of excess return relative to the incremental risk of the investment portfolio and is commonly used by portfolio managers for portfolio evaluation. In Table 2.11, I present the annual returns and information ratios to long-short portfolios formed from the top and bottom deciles under the three *CAP* assumptions and two valuation methods.

Table 2.10 presents the annual returns in each year and their associated Sharpe ratios, for valuations which assumed that *CAP* = 30 years. Comparable results are achieved when I assume that CAP = 10 or 20 years. Panel A presents the results for *DCF*-based portfolios while Panel B presents results for *Decision-tree* portfolios. The lower section of each panel presents *p*-values for matched pairs *t*-tests for differences in mean annual returns and Sharpe ratios. Stocks ranked in the top decile according to their *DCF* value relative to price had an annual Sharpe ratio of 0.79, compared to 0.39 for stocks ranked in the bottom decile (*p*-value = 0.11). Of the 45 *t*-tests for differences in mean Sharpe ratios, four are statistically significant in the expected direction – the Sharpe ratio for decile 1 portfolios is significantly greater than that for decile 3 and 8 portfolios; and the Sharpe ratio for decile 5 portfolios is significantly greater than that of decile 8 and 10 portfolios. If performance was random, the expected number of significant differences in Sharpe ratios would be 4-5, but half of these would occur in the direction opposite to expectations.

A similar result is obtained for stocks ranked according to *Decision-tree* value relative to price. The decile 1 portfolio had a mean Sharpe ratio of 0.76, compared to 0.37 for the decile 10 portfolio (*p*-value = 0.13). In this case, there were five instances in which there was a significant difference in the expected direction. The decile 4 portfolio had a significantly higher mean Sharpe ratio than the mean ratio resulting from portfolios formed from deciles 6, 8 and 10. And the decile 7 portfolio had a mean Sharpe ratio that was significantly higher than the mean ratio resulting from portfolios formed from deciles 8 and 10.

In sum, Table 2.10 provides support for the use of fundamental analysis in portfolio formation. There are significant differences in the Sharpe ratios of portfolios formed from decile rankings of value/price, which make a material difference to portfolio performance. If a portfolio manager can increase the Sharpe ratio of an investment portfolio by just 0.1, this corresponds to additional returns of 2 percent for a portfolio with a typical standard deviation of around 20 percent. However, there is no evidence that the use of *Decision-tree* valuations would have resulted in additional outperformance.

Table 2.10
Sharpe ratios according to deciles of stocks ranked according to value/price assuming the competitive advantage period is 30 years

In each year, I ranked stocks according to value/price, where value is estimated using a *DCF* or *Decision-tree* valuation model, and share price is the closing price at 30 April. I formed portfolios after grouping the stocks into deciles and measured the total return over 12 months, as well as Sharpe ratio. Returns are computed on a continuously-compounded basis. The Sharpe ratio is the annual return minus the risk-free rate, dividend by the annualised standard deviation of monthly returns. The risk-free rate is the yield on 10-year US Treasury bonds, converted to a continuously-compounded return. The valuation models are summarised in Exhibits 2.2 and 2.9. The sample comprises 9427 firm-years from 1987-2004, representing 1049 individual stocks.

Panel A: Portfolios formed according to Discounted Cash Flow valuations

	Annual returns (%)										Sharpe ratio									
Decile	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1987	-2.4	-4.5	-8.8	-3.8	-9.5	-2.2	-9.0	-11.3	-8.1	-9.0	-0.30	-0.37	-0.59	-0.45	-0.57	-0.33	-0.50	-0.53	-0.43	-0.38
1988	23.7	18.7	19.6	15.2	22.2	14.7	17.8	18.7	9.3	16.0	1.18	0.89	1.02	0.66	1.19	0.53	0.83	0.81	0.06	0.58
1989	-0.2	6.6	11.9	11.2	8.5	5.3	4.6	4.1	2.6	8.0	-0.59	-0.15	0.22	0.17	-0.01	-0.21	-0.26	-0.31	-0.45	-0.04
1990	14.4	10.9	19.9	21.3	21.7	23.8	26.8	18.1	30.1	21.6	0.18	0.08	0.50	0.74	0.57	0.67	0.77	0.41	0.88	0.48
1991	16.8	19.2	20.4	23.7	20.4	22.4	18.9	15.8	23.8	24.4	0.71	1.02	0.98	1.05	0.76	0.95	0.62	0.50	0.85	0.72
1992	22.4	30.2	17.2	15.3	14.8	12.1	13.1	6.7	15.1	19.3	1.09	1.99	1.38	0.57	0.61	0.66	0.73	-0.08	0.83	1.14
1993	19.2	1.0	12.2	5.3	5.1	6.4	12.3	8.2	10.0	15.8	1.35	-0.56	0.54	-0.07	-0.12	0.07	0.74	0.27	0.52	0.84
1994	15.6	8.7	14.0	13.4	11.8	13.5	17.3	15.7	23.3	12.3	0.74	0.20	0.78	0.70	0.43	0.72	1.00	0.82	1.46	0.45
1995	24.4	29.3	20.6	22.7	28.6	25.6	27.0	25.2	24.5	28.3	1.79	2.43	1.77	1.95	2.68	3.19	3.49	2.58	2.42	2.56
1996	23.1	23.7	12.4	19.7	16.1	21.8	16.4	12.2	18.7	4.4	0.97	1.03	0.48	1.10	0.75	1.33	0.72	0.37	0.90	-0.12
1997	49.5	30.9	33.5	32.9	39.0	28.7	28.5	30.0	35.9	36.2	2.83	1.86	2.40	1.71	2.68	1.52	1.23	1.74	2.13	2.28
1998	-15.4	-10.0	-18.3	-14.4	1.9	0.6	-3.7	5.6	3.7	4.7	-0.67	-0.59	-1.01	-0.91	-0.15	-0.19	-0.36	0.00	-0.06	-0.03
1999	0.3	-3.6	-10.8	0.2	11.2	1.9	1.0	7.5	15.6	8.7	-0.33	-0.68	-1.20	-0.37	0.49	-0.32	-0.30	0.18	0.70	0.22
2000	7.7	15.7	7.1	15.0	15.7	1.7	2.9	-2.9	0.4	-22.5	0.09	0.73	0.07	0.63	0.80	-0.32	-0.18	-0.41	-0.27	-0.73
2001	33.8	25.0	11.4	14.4	11.4	2.4	4.4	-10.2	1.1	-7.8	1.37	1.03	0.31	0.50	0.29	-0.15	-0.04	-0.70	-0.19	-0.56
2002	-16.1	-31.0	-21.7	-23.4	-19.6	-25.1	-17.9	-22.9	-19.8	-23.6	-0.81	-1.53	-1.01	-1.28	-1.12	-1.20	-0.99	-1.14	-0.92	-1.00
2003	57.9	49.4	40.4	34.4	40.7	35.0	32.1	35.5	35.6	27.3	4.90	3.53	2.79	3.47	2.85	2.18	2.72	2.75	2.60	1.37
2004	1.6	5.0	3.6	6.4	11.6	6.5	4.1	9.3	-9.7	-12.0	-0.17	0.04	-0.06	0.16	0.56	0.17	-0.03	0.44	-0.81	-0.79
Mean	15.4	12.5	10.3	11.6	14.0	10.8	10.9	9.2	11.8	8.5	0.79	0.61	0.52	0.57	0.71	0.52	0.57	0.43	0.57	0.39
StDev	19.6	18.6	16.5	14.9	14.7	14.2	13.7	14.7	15.8	17.5	1.41	1.27	1.11	1.10	1.08	1.05	1.11	1.04	1.06	1.00
t	3.3	2.9	2.6	3.3	4.0	3.2	3.4	2.7	3.2	2.1	2.39	2.04	1.98	2.22	2.77	2.09	2.16	1.74	2.26	1.66
P(t)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.03	0.06	0.06	0.04	0.01	0.05	0.05	0.10	0.04	0.12

	p-values for matched pairs *t*-tests for differences in mean annual returns								
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	0.18	**0.02**	0.13	0.60	0.13	0.12	**0.08**	0.27	**0.08**
2		0.25	0.61	0.49	0.48	0.53	0.30	0.82	0.30
3			0.24	**0.05**	0.75	0.67	0.66	0.55	0.55
4				0.10	0.59	0.63	0.30	0.95	0.32
5					**0.03**	**0.04**	**0.01**	0.29	**0.06**
6						0.92	0.22	0.56	0.32
7							0.21	0.58	0.28
8								0.16	0.73
9									0.10

	p-values for matched pairs *t*-tests for differences in mean Sharpe ratios								
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	0.29	**0.09**	0.17	0.65	0.23	0.28	**0.09**	0.28	0.11
2		0.51	0.75	0.51	0.57	0.81	0.37	0.84	0.33
3			0.64	0.21	0.97	0.76	0.58	0.78	0.43
4				0.25	0.67	0.97	0.31	0.97	0.38
5					0.14	0.33	**0.02**	0.36	**0.07**
6						0.50	0.40	0.67	0.38
7							0.18	1.00	0.23
8								0.27	0.79
9									0.15

Panel B: Portfolios formed according to Decision-tree valuations

	Annual return (%)										Sharpe ratio									
Decile	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1987	-2.4	-8.9	-0.5	-11.1	-6.9	-10.2	-4.2	-9.1	-7.3	-8.0	-0.30	-0.50	-0.28	-0.66	-0.50	-0.55	-0.39	-0.49	-0.43	-0.36
1988	21.8	18.6	16.0	18.2	21.5	13.7	19.4	18.3	14.9	13.7	1.07	0.87	0.63	0.87	1.08	0.46	0.91	0.90	0.49	0.41
1989	-1.9	7.7	11.7	13.1	10.6	-5.3	12.5	7.4	5.1	1.6	-0.69	-0.06	0.20	0.28	0.16	-0.86	0.24	-0.08	-0.28	-0.48
1990	14.0	10.3	18.9	23.7	22.1	24.5	28.4	24.1	21.8	20.8	0.17	0.06	0.49	0.77	0.65	0.66	0.84	0.67	0.51	0.52
1991	15.0	18.0	24.7	23.1	17.6	23.3	19.5	14.9	21.9	27.9	0.53	0.90	0.97	1.16	0.68	0.91	0.72	0.46	0.76	0.89
1992	25.1	25.5	21.1	15.7	15.9	8.3	15.3	7.8	12.7	19.0	1.29	1.50	1.38	0.70	0.86	0.11	1.31	0.05	0.68	1.13
1993	19.0	3.1	15.7	10.3	3.9	1.2	14.1	5.8	6.2	16.4	1.27	-0.30	0.89	0.59	-0.25	-0.54	0.92	0.00	0.04	0.99
1994	16.1	9.6	13.3	16.7	10.5	12.9	18.1	18.2	16.6	13.7	0.76	0.28	0.62	1.26	0.36	0.57	1.29	0.95	0.96	0.57
1995	24.7	26.0	25.3	24.5	24.7	27.2	27.8	27.3	22.7	25.6	1.81	2.41	1.91	2.25	2.81	2.95	4.14	2.83	1.94	2.87
1996	22.6	20.6	19.2	16.8	15.5	19.0	13.7	14.9	21.7	4.6	0.97	0.78	1.04	0.80	0.85	1.12	0.44	0.63	1.15	-0.12
1997	47.8	25.8	38.8	35.6	36.1	36.3	26.0	33.0	29.5	36.4	2.57	1.35	2.59	1.98	2.16	2.06	1.26	1.75	1.70	2.39
1998	-21.0	-18.5	-11.7	-3.8	-3.8	-1.2	-4.7	6.0	8.3	5.1	-0.81	-0.83	-0.77	-0.43	-0.41	-0.24	-0.41	0.02	0.10	-0.02
1999	4.0	2.0	1.4	-3.5	11.1	-0.2	9.2	-0.4	8.0	0.3	-0.08	-0.23	-0.33	-0.82	0.53	-0.38	0.35	-0.37	0.18	-0.30
2000	9.2	11.5	7.4	17.2	6.9	8.7	1.3	-2.5	4.8	-23.6	0.17	0.32	0.08	0.86	0.06	0.19	-0.29	-0.49	-0.06	-0.91
2001	36.8	15.9	8.9	14.2	9.2	1.1	2.8	-1.0	4.7	-6.7	1.41	0.53	0.17	0.46	0.19	-0.19	-0.12	-0.39	-0.02	-0.55
2002	-21.0	-25.5	-34.5	-18.4	-27.1	-18.2	-17.0	-16.8	-16.2	-26.5	-1.11	-1.11	-1.39	-0.86	-1.48	-0.95	-1.04	-1.00	-0.79	-1.21
2003	65.2	44.8	44.5	39.6	42.2	36.2	36.4	31.2	22.9	25.4	5.05	2.75	2.73	2.85	3.21	2.80	2.83	2.50	1.79	1.52
2004	-2.2	5.6	3.9	4.2	2.8	4.5	2.9	7.8	4.5	-7.7	-0.38	0.08	-0.03	-0.02	-0.10	0.01	-0.12	0.31	0.01	-0.72
Mean	15.1	10.7	12.5	13.1	11.8	10.1	12.3	10.4	11.3	7.6	0.76	0.49	0.60	0.67	0.60	0.45	0.72	0.46	0.48	0.37
StDev	21.7	16.8	17.8	15.1	15.8	15.4	13.6	13.7	11.6	17.6	1.45	1.03	1.08	1.02	1.16	1.16	1.23	1.03	0.78	1.12
t	2.96	2.69	2.96	3.70	3.18	2.79	3.84	3.22	4.12	1.85	2.23	2.01	2.38	2.77	2.20	1.66	2.47	1.88	2.64	1.40
P(t)	0.01	0.02	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.08	0.04	0.06	0.03	0.01	0.04	0.12	0.02	0.08	0.02	0.18

	p-values for matched pairs *t*-tests for differences in mean annual returns										*p*-values for matched pairs *t*-tests for differences in mean Sharpe ratios								
	2	3	4	5	6	7	8	9	10		2	3	4	5	6	7	8	9	10
1	**0.06**	0.29	0.47	0.24	0.14	0.40	0.21	0.32	**0.08**	1	0.15	0.35	0.63	0.39	0.16	0.85	0.19	0.24	0.13
2		0.26	0.15	0.47	0.80	0.45	0.91	0.81	0.39	2		0.31	0.12	0.25	0.78	0.14	0.83	0.98	0.51
3			0.67	0.64	0.26	0.93	0.37	0.61	**0.08**	3			0.52	0.99	0.31	0.51	0.31	0.34	0.11
4				0.35	**0.05**	0.61	0.13	0.31	**0.07**	4				0.62	**0.09**	0.78	**0.09**	0.14	**0.09**
5					0.28	0.73	0.39	0.75	0.12	5					0.16	0.41	0.20	0.36	0.17
6						0.21	0.84	0.42	0.35	6						0.11	0.95	0.77	0.63
7							0.15	0.49	**0.04**	7							**0.05**	0.17	**0.02**
8								0.45	0.21	8								0.79	0.53
9									0.13	9									0.40

Table 2.11 summarises the annual performance of long-short portfolios formed from the top and bottom deciles of stocks ranked according to value/price. The left-hand side presents the cumulative annual returns to these portfolios according to valuation method and *CAP* assumptions. The right-hand side presents the information ratio, which is the return on the long-short portfolio relative to the annualised standard deviation of monthly returns.

On average, long-short portfolios earned returns of around 7 percent a year and the p-values for two-tailed t-tests range from 0.08 to 0.16. The mean information ratio is in the range of 0.44 to 0.67, with p-values which range from 0.09 to 0.22. The mean information ratio increases with an increase in the assumed competitive advantage period and when *Decision-tree* valuations are performed instead of *DCF* valuations. However, these differences are not statistically significant.

The risk-adjusted performance of long-short portfolios supports the evidence presented above, which suggests that fundamental equity valuation is useful in achieving abnormal portfolio returns. However, inspection of the performance over particular time periods reveals that short-term underperformance can be severely negative. For example, the portfolios achieved large, significant negative returns in 1998, a year in which the MSCI Growth index outperformed its value-based counterpart by 14 percent. This performance was reversed in 2001, a year in which the MSCI Value Index outperformed the growth index by 39 percent.

Table 2.11
Returns to long-short portfolios by cohort year

In each year, I ranked stocks according to value/price, where value is estimated using a *DCF* or *Decision-tree* valuation model, and share price is the closing price at 30 April. I formed long-short portfolios from the top and bottom deciles of stocks in each year and under each valuation method. The table presents the annual returns to these portfolios and the information ratio. The information ratio is the annual return divided by the annualised standard deviation of returns. The valuation models are summarised in Exhibits 2.2 and 2.9. The sample comprises 9427 firm-years from 1987-2004, representing 1049 individual stocks.

	Annual returns						Information ratio					
	Discounted cash flows			*Decision-tree*			*Discounted cash flows*			*Decision-tree*		
CAP	**10**	**20**	**30**	**10**	**20**	**30**	**10**	**20**	**30**	**10**	**20**	**30**
1987	7.7	4.2	6.6	7.7	5.6	5.6	0.45	0.26	0.43	0.45	0.31	0.35
1988	10.0 ***	9.1 ***	7.7 ***	10.0 ***	8.2 ***	8.1 ***	1.42	1.23	1.01	1.37	1.12	1.07
1989	-4.0 **	-3.8 *	-8.2 ***	-2.7	-4.1 *	-3.4	-0.75	-0.55	-1.30	-0.43	-0.63	-0.45
1990	-18.6 ***	-9.7 **	-7.3 **	-19.0 ***	-10.5 ***	-6.7 *	-1.43	-0.82	-0.69	-1.51	-0.93	-0.54
1991	-4.7	-4.7	-7.6 *	-5.5	-11.0 **	-12.9 ***	-0.30	-0.32	-0.58	-0.33	-0.73	-1.00
1992	4.2	1.5	3.1	2.2	-5.8 **	6.1 **	0.48	0.21	0.44	0.24	0.72	0.72
1993	1.7	-1.7	3.4	5.0 ***	0.1	2.7	0.28	-0.23	0.50	0.91	0.02	0.37
1994	-1.5	0.6	3.3 **	-1.0	-0.5	2.4	-0.23	0.09	0.69	-0.17	-0.09	0.51
1995	-3.8	-3.6	-4.0	-4.3	-3.9	-0.8	-0.41	-0.33	-0.35	-0.42	-0.36	-0.08
1996	14.7 ***	12.4 ***	18.7 ***	12.7 ***	13.8 ***	18.0 ***	1.24	1.51	2.59	1.05	1.89	2.52
1997	7.7 ***	10.4 ***	13.3 ***	8.5 ***	10.3 ***	11.4 ***	0.95	1.18	1.69	0.99	1.01	0.95
1998	-26.1 ***	-22.2 ***	-20.1 ***	-26.9 ***	-23.8 ***	-26.1 ***	-2.31	-2.92	-2.79	-2.47	-3.50	-2.68
1999	-14.4 **	-15.1 **	-8.3	-10.4 *	-5.4	3.7	-0.83	-0.79	-0.39	-0.56	-0.24	0.15
2000	36.5 ***	33.2 ***	30.2 ***	36.0 ***	32.4 ***	32.8 ***	1.09	1.03	0.99	1.08	1.06	1.37
2001	57.0 ***	49.3 ***	41.6 ***	54.8 ***	48.9 ***	43.5 ***	3.12	3.14	3.23	3.35	3.40	4.00
2002	4.1	3.6	7.5 *	2.0	4.9	5.5	0.23	0.21	0.60	0.11	0.34	0.43
2003	26.4 ***	31.5 ***	30.7 ***	28.4 ***	40.5 ***	39.8 ***	2.52	3.01	3.12	3.10	4.79	3.89
2004	29.8 ***	24.0 ***	13.6 ***	25.6 ***	16.2 ***	5.6 *	2.32	1.96	1.16	2.12	1.65	0.57
Mean	**7.0**	**6.6**	**6.9**	**6.8**	**7.1**	**7.5**	**0.44**	**0.44**	**0.57**	**0.49**	**0.55**	**0.67**
StDev	**20.3**	**18.1**	**15.9**	**19.7**	**18.4**	**17.3**	**1.40**	**1.46**	**1.52**	**1.46**	**1.78**	**1.60**
t	**1.47**	**1.55**	**1.84**	**1.47**	**1.63**	**1.83**	**1.32**	**1.27**	**1.61**	**1.43**	**1.30**	**1.79**
P(t)	**0.16**	**0.14**	**0.08**	**0.16**	**0.12**	**0.08**	**0.20**	**0.22**	**0.13**	**0.17**	**0.21**	**0.09**

The evidence presented above suggests that if portfolio managers are assessed on short-term performance, they bear substantial risk from implementing a value-based investment strategy. I assess this risk by measuring the probability of underperformance, and the expected returns in the event of that underperformance. Say we assume the distributions of returns from the long-short investment strategies is uncorrelated over time. Also assume that the portfolio manager is evaluated on three-year investment performance. I ran a simulation of 10,000 long-short investment portfolios over three-year horizons from the distribution of portfolio returns presented in Table 2.11. The simulation results are presented in Table 2.12.

This simulation reveals that the probability of negative returns over a three-year investment horizon ranges from 21-29 percent, with an expected annual loss of 4.3 to 5.9 percent. The expected return in the event of a gain ranges from 10.2 to 21.1 percent. This leads to two conclusions regarding the full-sample performance. First, there is evidence of significant and material gains from investment strategies formed from fundamental analysis. But there is also material risk of underperformance, due to correlation with value-growth investment strategies.

Table 2.12
Probability of negative returns to a long-short portfolio strategy over a three-year investment horizon

In each year, I ranked stocks according to value/price, where value is estimated using a *DCF* or *Decision-tree* valuation model, and share price is the closing price at 30 April. I formed long-short portfolios from the top and bottom deciles of stocks in each year and under each valuation method. The annual returns to each portfolio are presented in Table 2.11. For each investment portfolio, I performed 10,000 simulations of portfolio returns over a three year investment horizon, assuming each return in Table 2.11 had an equal probability of occurrence and returns were uncorrelated over time. Table 2.12 presents the percentage of simulations in which the long-short portfolio would have earned positive or negative returns over a three-year investment horizon. It also presents the mean return to those portfolios, conditional upon the total return being positive or negative. The valuation models are summarised in Exhibits 2.9 and 2.9. The sample comprises 9427 firm-years from 1987-2004, representing 1049 individual stocks.

	Discounted cash flow portfolios			*Decision-tree* portfolios		
	CAP=10	CAP=20	CAP=30	CAP=10	CAP=20	CAP=30
Probability of loss (%)	29	29	22	28	26	21
Expected loss in the event that loss occurs (%)	5.8	4.8	4.3	5.9	4.8	5.0
Probability of gain (%)	71	71	78	72	74	79
Expected gain in the event that gain occurs (%)	12.1	11.1	10.2	11.7	11.3	10.9

As a further illustration of the impact of the value-growth bias on portfolio selection, I present a summary of the annual returns to long-short portfolios formed amongst stocks classified as high- or low-growth. Stocks in IBES industry sectors Technology, Healthcare and Consumer services formed part of the high-growth segment, while the remaining stocks formed part of the low-growth segment. Table 2.13 presents a summary of the performance of long-short portfolios formed according to deciles and quintiles from these two segments.

Mean annual returns are positive throughout, but the minimum p-value achieved by any portfolio is 0.12. However, if we compute t-statistics based on the distribution of monthly returns, returns are significantly greater than zero in several instances. What is most striking is the variability in annual performance, especially from 1998 to 2001. Performance is consistently negative for portfolios formed in 1998 and 1999, but these negative returns are more than recovered in the subsequent two years.

There is some association between the *CAP* assumption and performance amongst the sub-samples, but these differences are not significant. Specifically, performance of portfolios amongst low-growth stocks was highest when a short *CAP* was assumed. When using *DCF* valuations the mean annual return for long-short portfolios formed according to deciles was 4.9, 2.3 and 2.1 percent for *CAP* assumptions of 10, 20 and 30 years. But for portfolios formed from growth stocks we observe an increase in mean returns with an increase in the assumed *CAP*. Again referring to *DCF* valuations, the portfolios formed from deciles had mean returns of 7.7, 7.8 and 8.4 percent for *CAP* assumptions of 10, 20 and 30 years. Given the lack of significant differences in these returns, we cannot make a judgement as to an appropriate *CAP* assumption for growth or value stocks in the future. All we can conclude, is that during the period under study, it would have been worthwhile to value high-growth stocks using a long *CAP* assumption, and equally worthwhile to assume a short *CAP* to value low-growth stocks.

Table 2.13
Returns to long-short portfolios formed within high-growth and low-growth industries

I partitioned the sample into two sub-samples based on initial growth rates for the stocks' IBES industry sectors. High-growth sectors are Technology, Healthcare and Consumer Services and low-growth sectors are Basic industries, Capital goods, Consumer durables, Consumer non-durables, Energy, Finance, Transport and Utilities. For each sub-sample in each year, I ranked stocks according to value/price, where value is estimated using a *DCF* or *Decision-tree* valuation model, and share price is the closing price at 30 April. I formed long-short portfolios from the top and bottom deciles of stocks and top and bottom quintiles. The table presents the continuously-compounded annual returns to these portfolios, where "1 v 10" refers to portfolios formed from the top and bottom deciles and "1-2 v 9-10" refers to portfolios formed from the top and bottom quintiles. The valuation models are summarised in Exhibits 2.2 and 2.9. The sample comprises 9427 firm-years from 1987-2004, representing 1049 individual stocks.

	Discounted cash flow **valuations**												***Decision-tree*** **valuations**											
	CAP = 10 years				CAP = 20 years				CAP = 30 years				CAP = 10 years				CAP = 20 years				CAP = 30 years			
	1 v 10		1-2 v 9-10		1 v 10		1-2 v 9-10		1 v 10		1-2 v 9-10		1 v 10		1-2 v 9-10		1 v 10		1-2 v 9-10		1 v 10		1-2 v 9-10	
	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
Annual returns																								
1987	14.7	-0.9	12.6	-4.3	11.8	-7.4	16.9	-4.4	19.2	-5.2	17.7	-3.0	14.7	-0.8	12.6	-4.4	8.9	-3.5	15.0	-5.7	18.9	17.9	-3.4	-7.1
1988	16.9	8.8	9.3	5.4	16.0	5.0	7.4	8.0	16.6	3.8	10.9	8.1	16.9	8.8	9.3	5.6	18.8	5.7	8.6	6.8	16.6	0.4	6.4	6.3
1989	13.0	-7.9	3.7	-6.2	2.3	-9.6	4.0	-7.3	5.8	-14.2	4.2	-6.7	13.0	-8.1	-0.6	-8.0	6.1	-11.3	4.5	-8.5	8.8	7.2	-11.0	-2.6
1990	-16.3	-9.1	-9.5	-3.4	-19.2	-6.9	-22.6	-2.9	-15.1	-4.6	-19.2	-4.7	-15.0	-10.2	-12.5	-3.4	-17.5	-8.6	-13.1	-4.9	-9.4	-16.8	-4.3	-4.8
1991	-4.6	1.0	-1.1	-4.4	-15.2	-7.3	1.6	-7.2	-13.9	-10.1	-4.7	-8.3	-12.4	-4.1	-2.8	-4.0	-15.2	-11.4	-5.0	-9.9	-10.6	-5.0	-12.8	-10.4
1992	-1.0	5.5	10.4	6.9	1.3	8.9	10.6	6.8	-8.6	6.8	7.2	6.6	7.4	3.1	9.2	6.9	6.9	4.8	8.8	5.8	-2.8	10.7	5.4	6.5
1993	-7.0	3.7	2.4	0.4	-8.7	1.9	-8.4	1.2	-4.6	2.2	-12.6	2.1	-9.6	0.9	2.0	1.9	-5.7	1.9	-3.5	2.2	-6.8	-10.0	1.1	3.1
1994	-6.7	7.6	-12.4	1.9	-6.9	8.8	-10.3	0.9	-6.5	4.3	-6.3	-0.5	-6.4	7.2	-10.7	1.2	-4.1	7.8	-5.9	1.5	9.8	-1.2	3.0	-0.5
1995	-11.0	-1.3	-4.2	-4.3	-6.0	-4.2	-4.7	-3.7	-0.9	-1.3	3.6	-2.7	-11.0	-0.7	-6.9	-2.2	-9.8	-3.7	-4.2	-1.0	-1.6	2.4	-0.1	-0.7
1996	21.0	15.6	10.2	6.6	21.2	15.1	8.1	10.9	27.9	21.8	8.1	13.3	14.4	15.5	13.2	8.4	24.5	15.9	8.4	11.2	18.8	4.3	18.2	10.8
1997	11.8	6.6	6.8	4.9	15.6	4.3	4.2	6.4	10.3	9.0	4.3	6.1	10.1	4.2	5.8	3.0	12.6	7.6	4.2	6.3	0.8	4.8	13.1	6.9
1998	-26.3	-21.2	-22.7	-15.1	-19.8	-23.0	-26.7	-15.2	-24.1	-25.3	-16.5	-13.3	-29.9	-23.5	-24.3	-13.8	-19.4	-23.5	-28.7	-16.4	-23.0	-29.2	-33.5	-22.1
1999	-42.9	6.9	-41.2	0.3	-38.1	-1.4	-34.2	-2.2	-24.1	-2.9	-32.2	-2.8	-44.6	6.9	-36.6	1.6	-36.5	6.8	-29.7	1.6	-28.4	-22.6	6.8	5.2
2000	52.1	-0.8	39.1	2.6	47.9	-2.0	40.0	2.0	43.6	2.2	43.6	0.6	60.6	0.3	45.0	2.4	49.8	2.7	37.3	4.6	54.1	35.9	5.6	3.7
2001	63.9	34.3	66.0	28.9	61.5	28.0	58.6	24.0	60.2	22.3	49.0	19.0	66.8	35.3	65.9	27.7	61.7	30.1	55.7	19.8	59.6	49.0	15.0	9.0
2002	3.1	-2.3	-2.6	-3.0	20.6	-2.7	-6.3	0.4	14.6	-1.0	-2.1	-5.2	2.1	-2.3	-1.4	-6.1	12.0	-3.2	-4.0	-4.8	16.5	-1.7	7.8	-6.0
2003	34.0	23.8	30.5	20.0	36.5	21.0	29.4	20.6	34.4	16.5	30.8	20.3	37.2	23.3	31.4	22.2	51.7	22.3	34.5	25.8	47.4	36.8	30.2	24.9
2004	24.1	17.8	23.6	9.2	20.0	13.0	19.2	7.6	16.9	12.9	10.7	2.0	14.8	22.5	18.6	10.4	4.6	15.2	8.8	7.7	3.3	1.0	17.2	4.9
Mean	7.7	4.9	6.7	2.6	7.8	2.3	4.8	2.5	8.4	2.1	5.4	1.7	7.2	4.3	6.5	2.7	8.3	3.1	5.1	2.3	9.5	4.7	3.6	1.5
St Dev	26.3	12.7	23.7	10.0	25.2	12.2	23.1	9.7	23.3	12.1	20.8	9.1	28.0	13.6	23.9	10.1	26.1	13.0	21.4	10.3	24.4	20.2	14.0	10.0
T	1.24	1.64	1.20	1.09	1.32	0.80	0.89	1.11	1.54	0.72	1.10	0.80	1.09	1.35	1.15	1.15	1.35	1.01	1.01	0.96	1.66	0.97	1.09	0.64
P(t)	(0.23)	(0.12)	(0.25)	(0.29)	(0.21)	(0.43)	(0.39)	(0.28)	(0.14)	(0.48)	(0.29)	(0.44)	(0.29)	(0.19)	(0.26)	(0.27)	(0.19)	(0.33)	(0.33)	(0.35)	(0.12)	(0.34)	(0.29)	(0.53)
Monthly returns																								
Mean	0.64	0.41	0.56	0.21	0.65	0.19	0.40	0.21	0.70	0.17	0.45	0.14	0.60	0.36	0.54	0.23	0.69	0.26	0.42	0.19	0.80	0.39	0.30	0.13
St Dev	6.37	3.41	4.81	2.66	6.06	3.33	4.70	2.63	5.88	3.08	4.39	2.53	6.41	3.36	4.81	2.64	5.71	3.32	4.59	2.51	5.48	4.43	3.33	2.52
t	1.48	1.76	1.71	1.18	1.58	0.85	1.26	1.18	1.76	0.82	1.50	0.83	1.37	1.58	1.66	1.28	1.78	1.14	1.36	1.14	2.13	1.29	1.33	0.73
P(t)	(0.14)	**(0.08)**	**(0.09)**	(0.24)	(0.11)	(0.39)	(0.21)	(0.24)	**(0.08)**	(0.41)	(0.14)	(0.41)	(0.17)	(0.12)	**(0.10)**	(0.20)	**(0.08)**	(0.26)	(0.18)	(0.26)	**(0.03)**	(0.20)	(0.19)	(0.47)

I account for the value-growth preference in two ways. First, I measure the performance of investment portfolios formed within sub-samples partitioned on the basis of size and the market-to-book equity ratio, as well as sub-samples formed on the basis of industry growth expectations. Second, in Sub-section 5.2 I control for these factors by estimating the intercept term on regressions of returns on a four-factor model, where the explanatory factors are market returns, size, the book-to-market ratio and momentum.

5.1.2 Four sub-samples partitioned on the basis of size and the market-to-book ratio

The year-by-year performance of investment portfolios formed on the basis of value relative to price suggests the valuations favour the purchase of value stocks. Analysis of portfolio characteristics supports this contention. Table 2.14 presents the mean market capitalisation and market-to-book ratio of stocks in each decile after ranking according to value/price.

Table 2.14
Mean market capitalisation and market-to-book ratio of stocks according to decile rankings of value/price

In each year, I ranked stocks according to value/price, where value is estimated using a *DCF* or *Decision-tree* valuation model, and share price is the closing price at 30 April. I formed portfolios after grouping the stocks into deciles. Table 2.14 shows the annual mean market capitalisation and market-to-book equity ratio for each decile portfolio formed under each valuation method, and each assumption regarding the competitive advantage period (10, 20 or 30 years). The final column shows the ratio of annual mean market capitalisation or market-to-book ratio for stocks ranked in the top and bottom decile. The valuation models are summarised in Exhibits 2.2 and 2.9. The sample comprises 9427 firm-years from 1987-2004, representing 1049 individual stocks.

Decile	1	2	3	4	5	6	7	8	9	10	1/10
Mean market capitalisation ($b)											
DCF(CAP=10)	2.8	3.7	5.2	6.9	8.6	11.3	10.5	12.1	14.6	16.9	0.17
DCF(CAP=20)	2.8	4.0	4.9	7.4	8.6	11.1	10.9	12.3	15.1	15.4	0.18
DCF(CAP=30)	2.7	4.2	5.1	7.3	8.7	10.7	11.4	13.4	14.7	14.3	0.19
DT (CAP=10)	2.7	3.8	5.1	7.1	8.5	9.6	10.7	12.2	15.0	18.0	0.15
DT (CAP=20)	2.9	3.7	4.7	6.1	8.3	8.9	10.8	11.7	16.3	19.2	0.15
DT (CAP=30)	2.8	3.7	4.5	6.1	7.5	9.1	10.0	13.7	15.6	19.6	0.14
Mean market-to-book ratio											
DCF (CAP=10)	2.1	2.0	2.9	3.2	3.1	4.1	4.1	4.9	5.5	9.0	0.23
DCF (CAP=20)	2.3	2.1	2.9	3.4	3.3	3.8	4.3	5.1	5.4	8.3	0.28
DCF (CAP=30)	2.5	2.5	2.6	3.4	3.5	3.8	4.5	5.1	5.2	7.7	0.33
DT (CAP=10)	2.1	2.1	2.8	3.1	3.3	3.8	4.3	5.0	5.7	8.8	0.24
DT (CAP=20)	2.6	2.1	3.0	3.1	3.5	3.6	4.0	4.9	6.1	8.2	0.31
DT (CAP=30)	2.8	2.6	2.7	3.4	3.4	3.8	4.0	5.3	5.3	7.8	0.36

The data in Table 2.14 provides important information on two fronts. Clearly, the fundamental valuation models identify small stocks, and low market-to-book stocks as being undervalued. On average, stocks ranked in the top decile according to value/price are about one-sixth the size of stocks ranked in the bottom decile, and have market-to-book ratios roughly one-quarter of those in the bottom decile. However, the preference for low market-to-book stocks declines as the assumed competitive advantage period increases. This occurs because, with a longer *CAP*, firms are assumed to maintain high revenue growth and margins for longer, thereby making growth stocks appear relatively more valuable.

Given that the valuation models clearly identify small stocks and low market-to-book stocks as relatively undervalued, I address two issues. First, do we observe the comparable investment performance across sub-samples partitioned according to size and the market-to-book ratio; or do we only observe superior performance when we select stock at the extremes of the value/growth spectrum? Second, do we observe outperformance after accounting for the known explanatory power of size and the market-to-book ratio in explaining returns? I address the second question in Sub-section 5.2. Below, I assess the performance of four equal-sized sub-samples formed on the basis of size and the market-to-book ratio. In each year, I divided the sample in two, according to the median market-to-book ratio, and then split these samples in two according to their median market capitalisation. So, we have the following investment portfolios:

1. Small, low market-to-book stocks;
2. Large, low market-to-book stocks;
3. Small, high market-to-book stocks;
4. Large high market-to-book stocks.

Table 2.15 summarises the investment performance of these portfolios, assuming a competitive advantage period of 30 years. Columns 2-11 present the mean annual returns and Sharpe ratios, and column 12 shows the number of times there was a significant difference (p-value ≤ 0.10) between deciles in the expected direction. Recall that there are 45 comparisons and the p-values refer to two-tailed significance tests. So we would expect to see no more than 2-3 instances of significant t-statistics in the expected direction. Columns 13-16 show the performance of long-short portfolios formed on the basis of the top and bottom quintiles. I selected quintiles in this instance to ensure the portfolios were of a size somewhat comparable to those held by investment managers. Portfolio size ranges from 27 to 94 stocks. I show the mean annual return and information ratio, as well as the p-value of t-tests of whether the mean is significantly different from zero.

Table 2.15
Portfolio performance amongst sub-samples formed on the basis of size and the market-to-book ratio assuming a competitive advantage period of 30 years

In each year, I partitioned the sample into four equal-sized sub-samples according to size and the market-to-book equity ratio. First, in each year I formed two equal-sized groups after ranking stocks according to market-to-book equity. Second, within those groups, I ranked stocks according to market capitalisation. For each of the four sub-samples in each year, I ranked stocks according to value/price, where value is estimated using a *DCF* or *Decision-tree* valuation model, and share price is the closing price at 30 April. Valuations assumed a competitive advantage period of 30 years. The table presents the mean annual returns to stocks in each decile and the mean Sharpe ratio. The Sharpe ratio in each year is the mean annual return minus the risk-free rate, divided by the annualised standard deviation of monthly returns. The risk-free rate is the yield on 10-year US Treasury bonds, computed on a continuously-compounded basis. I compared the mean annual returns and Sharpe ratios across deciles and tested for a significant difference in means. In each case, there are 45 tests for difference in means. Column 12 labelled "N/45" shows the number of cases in which (1) there was a difference in means that was statistically significant at the 10 percent level for a two-tailed test; and (2) this difference was in the expected direction (higher mean for stocks ranked in higher deciles according to the value/price ratio. I also formed long-short portfolios according to quintiles and computed the mean annual returns to these portfolios. Columns 13-14 present these mean returns and the *p*-value for a two-tailed test of significance. For these long-short portfolios, I computed the information ratio in each year, which is the annual return divided by the standard deviation of monthly returns. I then computed the mean information ratio for the 18 years of returns. Columns 15-16 present these mean information ratios and the *p*-value for a two-tailed test against an expected value of zero. The valuation models are summarised in Exhibits 2.2 and 2.9. The sample comprises 9427 firm-years from 1987-2004, representing 1049 individual stocks.

Mean annual returns (%) and mean Sharpe ratios (In each section, returns are in the upper two rows; Sharpe ratios are in the lower two rows)											N/45	Return to long-short quintile		Information ratio	
Decile	1	2	3	4	5	6	7	8	9	10		Mean	*p*	Mean	*p*
(1) Small, low market-to-book															
DCF	14.4	18.5	16.9	11.7	14.1	12.3	13.7	15.1	12.0	15.7	3	2.6	0.42	0.11	0.62
DT	16.2	13.5	15.3	15.7	13.3	12.4	13.6	14.3	15.4	14.1	0	0.1	0.98	0.03	0.93
DCF	0.81	0.83	0.79	0.65	0.63	0.61	0.56	0.90	0.54	0.58	0				
DT	0.75	0.64	0.75	0.80	0.55	0.59	0.59	0.74	0.72	0.59	0				
(2) Large, low market-to-book															
DCF	12.5	10.9	10.9	9.5	11.1	10.1	10.7	8.8	11.7	8.5	0	1.6	0.55	0.34	0.25
DT	13.2	9.7	10.6	12.0	9.5	10.7	10.6	8.7	11.2	8.8	2	1.5	0.55	0.40	0.19
DCF	0.69	0.55	0.50	0.43	0.49	0.46	0.53	0.31	0.40	0.30	4				
DT	0.71	0.47	0.48	0.61	0.35	0.52	0.45	0.33	0.35	0.28	4				
(3) Small, high market-to-book															
DCF	14.0	14.7	17.8	11.7	13.8	14.3	7.8	11.1	14.1	8.4	6	3.1	0.55	0.18	0.57
DT	13.1	18.1	13.7	13.8	12.1	12.0	12.5	15.0	8.5	8.7	7	6.9	0.48	0.55	**0.06**
DCF	0.53	0.46	0.68	0.39	0.53	0.51	0.25	0.45	0.42	0.33	3				
DT	0.47	0.61	0.44	0.56	0.48	0.39	0.48	0.69	0.25	0.32	4				
(4) Large, high market-to-book															
DCF	6.8	9.8	6.3	10.5	8.6	7.7	8.5	10.5	9.6	4.4	3	1.3	0.70	0.00	1.00
DT	6.6	10.0	7.3	9.5	8.9	9.3	9.0	10.2	6.1	5.9	0	2.2	0.70	0.09	0.74
DCF	0.18	0.32	0.13	0.49	0.31	0.40	0.39	0.46	0.41	0.17	2				
DT	0.19	0.32	0.25	0.43	0.44	0.35	0.41	0.38	0.15	0.19	1				

The results presented in Table 2.15 suggest that the fundamental investment strategies were most effective when used to select amongst small, growth stocks. If we compare the mean returns across deciles we see there were six or seven instances in which the mean returns were significantly greater for stocks ranked in higher deciles, compared to an expected number of 2-3. This outperformance is mitigated to some degree when portfolio volatility is considered, as there were 3 or 4 instances in which the mean Sharpe ratio is significantly greater for a high-ranked decile. In addition, the mean information ratio for long-short quintile portfolios formed using *Decision-tree* valuations is 0.55, which is significantly greater than zero with a *p*-value of 0.06.

The other sub-sample in which there is some evidence of outperformance is the portfolio of large, low market-to-book stocks. The primary benefit in this case appears to be risk-reduction, as there are no cases in which stocks ranked in a higher decile according to value/price have significantly higher mean returns than those ranked in a lower decile. However, for both the *DCF* and *Decision-tree* based portfolios, there are four instances in which the Sharpe ratio is higher for portfolios in a higher decile. The highest mean Sharpe ratios are 0.69 and 0.71, both achieved by stocks ranked in decile 1.

These results are informative because the two sub-samples in which there is evidence of outperformance are not at the extremes of the standard value/growth dichotomy. For small, low market-to-book stocks, there is weak evidence of higher investment returns from a fundamental investment strategy (three significant mean return comparisons) but there are no instances in which there was a significant difference in mean Sharpe ratios. For large, high market-to-book stocks we observe a comparable result, with the number of significant mean Sharpe ratio comparisons still below the threshold we would observe by chance.

In sum, the results presented in Sub-section 5.1 suggest that risk-adjusted performance is achievable. This performance was most consistent amongst small, growth stocks. However, there was no evidence of outperformance amongst large growth stocks or small value stocks. Any additional returns from selecting stocks from these sub-samples appears attributable to their greater risk. In the following section I continue to examine the relationship between portfolio performance, size and the market-to-book ratio in a linear regression framework.

5.2 Regression results

In Sub-section 5.1 I analysed the performance of investment portfolios on a raw returns and risk-adjusted basis, where is risk as measured as the volatility of monthly returns. In this section, I analyse portfolio performance from the perspective of a portfolio manager whose objective is to maximise "alpha" – the returns above the expected return, given factors known to be associated with returns. The expected returns model I use incorporates four factors, market risk, size, the book-to-market ratio and returns momentum. The association between returns the first three factors was quantified by Fama and French (1992, 1993) and has become known in the literature as the Fama-French three factor-model. Carhart (1997) documented a positive association between mutual fund returns and the returns of their underlying stocks over the previous 12 months. Controlling for momentum has now become standard in the literature, but the measurement of this factor varies.

In this section my analysis is independent of whether these factors are measuring risk, or whether they simply capture characteristics of undervalued stocks. The issue here is simply to determine whether a fundamental investment strategy is able to earn excess returns over that of a trading strategy based on the four factors listed above. In Sub-section 5.3, I discuss the issue of whether size and the book-to-market are likely to capture an equity risk factor, and the likely impact on the cost of capital. This discussion focuses on their association with credit ratings.

As with the analysis summarised in Sub-section 5.1, I formed long-short portfolios each year, after ranking stocks according to value/price using both the *DCF* and *Decision-tree* valuation methods, under three assumptions regarding the competitive advantage period (10, 20 or 30 years). I then regressed these portfolios' 216 monthly returns on the four-factor model below:

$$\left(R_{long} - R_{short}\right)_i - R_{f,i} = \alpha + \beta\left(R_m - R_f\right)_i + sSMB_i + hHML_i + mMOM_i + \varepsilon_i \quad (2.68)$$

where:

$R_m - R_f$ = the return to a value-weighted portfolio of all US-listed stocks minus the risk-free rate;

SMB = the average return on three equally-weighted portfolios of small stocks minus the average return to three equally-weighted portfolio of big stocks (the three portfolios in each case refer to those classed as value, neutral and growth based on their book-to-market ratios);

HML = the average return to two equally-weighted portfolios of high book-to-market equity stocks minus the average return to two equally-weighted portfolios of low market-to-book equity stocks (the two portfolios in each case refer to those classified as small and large, based on their market capitalisation); and

MOM = the average return to two portfolios with high cumulative returns from 12 to 2 months prior to the returns month, minus the average returns to two equally-weighted portfolios of stocks with low cumulative returns for the same prior period (stocks classified as having high cumulative returns are above the 70th percentile of stock returns while stock classified as having low cumulative returns are below the 30th percentile; the two portfolios in each case refer to those classed as small and large according to market capitalisation).

These factors are the same as those used in the studies by Fama and French and were downloaded from Ken French's website. I converted the returns to continuous time so they are measured on a comparable basis to the returns reported in Sub-section 5.1. I also conducted the analysis with all returns measured in discrete time. This had no material impact on the results. I repeated the analysis by regressing the portfolios' 18 annual returns on annual factors. In this instance, I omitted the market returns variable, due to a general lack of significance of the beta coefficient and its negative impact on explanatory power, due to a reduction in degrees of freedom. I performed this analysis on the full sample, the four sub-samples based on size and the market-to-book ratio, and on two sub-samples formed on the basis of industry growth characteristics.

The results provide evidence of outperformance, even after controlling for the four explanatory factors. For the full sample, the intercept term was in the range of 0.40 to 0.57 for portfolios formed on the basis of the top and bottom deciles of stocks. The magnitude of these coefficients increases with an increase in the assumed competitive advantage period, with statistical significance also improving. But there is no significant difference between the estimated intercept terms. Therefore, we cannot conclude that future portfolio performance is likely to be enhanced by assuming a longer *CAP* in valuations. All the results imply is that this assumption would have resulted in higher excess returns over the 18-year period under study.

For the sub-samples formed on the basis of size and the market-to-book ratio, the only significant intercept terms from the monthly returns regressions are drawn from the sub-sample of small, high market-to-book stocks. This is consistent with the evidence presented in Sub-section 5.1.2. For the annual returns results there are also significant intercept terms amongst both low market-to-book sub-samples. Finally, there is no material difference in excess returns amongst the sub-samples formed according to revenue growth.

5.2.1 Full sample

Table 2.16 presents the regression results for the full sample. For portfolios formed on the basis of the top and bottom deciles according to value/price, we observe significant intercept terms from the regressions of monthly returns. The highest intercept term of 0.57 percent is obtained when the *Decision-tree* valuation model is used, with a *CAP* assumption of 30 years. Intercept terms consistently increase with the *CAP* assumption, but remain insignificantly different from each other, and explanatory power decreases. We also observe a decrease in exposure to the *HML* factor. This is consistent with the evidence presented earlier that increasing the *CAP* assumption reduces the portfolio bias towards low market-to-book stocks. But there is no material change in exposure to the size factor. The negative beta coefficients mean that the valuation techniques typically identified stocks as relatively undervalued if they had less exposure to the market. The coefficients range from -0.09 to -0.19, which translates to a cost of equity differential of around 0.5 to 1.0 percent, when applied to an equity risk premium of 6 percent.

Referring to the results of portfolios formed from the top and bottom quintiles, and the top and bottom 30 percent of stocks, we see intercept terms decrease and lose statistical significance for most portfolios. Note that for consistency I have used two-tailed significance tests throughout the paper. So the *p*-values of 0.15-0.23 for the portfolios formed from the 30/40/30 split correspond to an estimated probability of around 8-12 percent that a fundamental investment strategy is actually detrimental to performance.

The results from the regressions on annual returns are consistent with those from the monthly returns, but explanatory power increases. As the *CAP* assumption increases we see the same decreased exposure to the *HML* factor as well as some reduction in exposure to the size factor.

5.2.2 Four sub-samples partitioned on the basis of size and the market-to-book ratio

Turning to the analysis of sub-samples formed on the basis of size and the market-to-book ratio, we observe significant alphas from the monthly regressions only from the sub-sample of small, high market-to-book stocks. This is consistent with the evidence presented in Sub-section 5.1.2. In that section, I compared the annual returns and Sharpe ratios amongst deciles formed each year according to rankings of value/price. This analysis showed significantly higher raw and risk-adjusted performance amongst stocks ranked in higher deciles, primarily concentrated in this sub-sample. Further, this was the only sub-sample which had a significantly positive mean information ratio for a long-short portfolio formed on the basis of quintiles.

In Table 2.17, we see that there are three significant intercept terms obtained from the long-short portfolios formed from deciles, and one significant intercept term obtained from the long-short portfolios formed from quintiles. There are a further three occasions in which the *p*-value associated with the intercept term is less than 0.2, which is consistent with there being a less than 10 percent chance that detrimental performance is likely to occur. We also see that the two high market-to-book portfolios have the most exposure to the *HML* factor. This implies that, within the broader class of high market-to-book stocks, there was a segment whose market values differed from theoretical values by a particularly large margin.

The annual regression results are broadly consistent with those of the monthly regression results. However, we do observe some significant intercept terms amongst the two portfolios of low market-to-book stocks. However, once we consider the totality of the evidence – the mean returns and Sharpe ratios from Section 5.1.2, and the monthly and annual regression results – the most consistent performance of the investment strategy is found amongst the small, high market-to-book sub-sample. What is equally clear is the lack of evidence of outperformance amongst large, high market-to-book stocks, which are likely to comprise a substantial portion of investment portfolios. Amongst this sub-sample there were few instances of significantly higher mean Sharpe ratios amongst higher-ranking deciles and no significant intercept terms amongst the regressions.

5.2.3 Two sub-samples partitioned on the basis of high- and low-growth industries

Finally, I conducted the same analysis on sub-samples formed on the basis of high- and low-growth industries, where high-growth industries were defined to be those from the Technology, Healthcare and Consumer Services sectors. Amongst the high-growth industry sub-sample, there is a clear preference in the portfolios for small, low market-to-book stocks, as shown by the large coefficients on *SMB* and *HML*. There remains evidence of outperformance, as shown by several significant intercept terms on the monthly regressions.

There is more consistent evidence of outperformance amongst portfolios formed from the high-growth portfolios. For stocks selected from this sub-sample, intercept terms are generally higher when compared to stocks selected from the low-growth sub-sample using the same methodology. For instance, when stocks were selected from the top and bottom deciles according to *Decision-tree* value/price, the intercept term from the monthly regression was 0.69, compared to 0.36 for that obtained from the low-growth sub-sample using the same valuation method. This relationship is maintained for the majority of comparisons. But none of these comparisons are statistically significant. Thus, the relative outperformance amongst portfolios formed from growth stocks could simply be due to the volatile returns accruing to these stocks from 1998-2001. All we can conclude is that, during a period in which returns to growth stocks were particularly volatile, a fundamental investment strategy would have achieved relatively better performance amongst high-growth rather than low-growth stocks.

Table 2.16
Regression results – Full sample

Table 2.16 presents the results of regression analysis where the dependent variable is returns to long-short portfolios formed on the basis of value relative to price. These portfolios are equally-weighted and comprise either the top and bottom 10, 20 or 30 percent of stocks ranked by value/price on 30 April each year from 1987-2004. The independent variables are $R_m - R_f$ (the return to a value-weighted portfolio of all US-listed stocks minus the risk-free rate), *SMB* (the return to an equally-weighted portfolio of small stocks minus the return to an equally-weighted portfolio of big stocks), *HML* (the return to an equally-weighted portfolio of high book-to-market equity stocks minus the return to a portfolio of low market-to-book equity stocks), and *MOM* (the return to a an equally-weighted portfolio of stocks with high cumulative returns from 12 to 2 months prior to portfolio formation, minus the returns to an equally-weighted portfolio of stocks with low cumulative returns). The regressions are conducted using both monthly and annual returns. Hence, the regression model is: $(R_{long} - R_{short})_i - R_{f,i} = \alpha + \beta(R_m - R_f)_i + sSMB_i + hHML_i + mMOM_i + \varepsilon_i$ where i refers to month 1 to 216 or year 1 to 18. In the regressions on annual returns, the market returns variable is omitted due to a general lack of statistical significance and its negative impact on explanatory power. The valuation models are summarised in Exhibits 2.2 and 2.9. The sample comprises 9427 firm-years from 1987-2004, representing 1049 individual stocks.

Panel A: Monthly returns

		DCF valuations			*Decision-tree* valuations		
	CAP (yrs)	**10**	**20**	**30**	**10**	**20**	**30**
1 minus 10	Alpha (%)	0.41	0.47	0.49	0.40	0.49	0.57
	p-value	**(0.08)**	**(0.04)**	**(0.03)**	**(0.08)**	**(0.04)**	**(0.02)**
	Beta	-0.17	-0.19	-0.14	-0.15	-0.15	-0.09
	p-value	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)	(0.13)
	SMB	0.36	0.33	0.32	0.40	0.35	0.37
	p-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	HML	0.84	0.68	0.60	0.84	0.64	0.51
	p-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	MOM	-0.05	-0.09	-0.07	-0.06	-0.05	-0.07
	p-value	(0.30)	(0.07)	(0.15)	(0.18)	(0.25)	(0.14)
	Adj-R^2 (%)	45	38	32	44	32	22
1-2 minus 9-10	Alpha (%)	0.28	0.26	0.23	0.28	0.23	0.19
	p-value	**(0.09)**	(0.13)	(0.17)	**(0.09)**	(0.15)	(0.28)
	Beta	-0.15	-0.14	-0.09	-0.14	-0.07	-0.02
	p-value	(0.00)	(0.00)	(0.03)	(0.00)	(0.06)	(0.62)
	SMB	0.30	0.29	0.27	0.34	0.33	0.34
	p-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	HML	0.67	0.61	0.52	0.67	0.58	0.44
	p-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	MOM	-0.08	-0.06	-0.05	-0.07	-0.05	-0.02
	p-value	(0.01)	(0.09)	(0.13)	(0.04)	(0.10)	(0.56)
	Adj-R^2 (%)	50	45	35	52	42	26
1-3 minus 8-10	Alpha (%)	0.18	0.19	0.17	0.18	0.18	0.16
	p-value	(0.17)	(0.15)	(0.18)	(0.17)	(0.17)	(0.23)
	Beta	-0.13	-0.10	-0.09	-0.11	-0.06	0.00
	p-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.07)	(0.90)
	SMB	0.26	0.25	0.23	0.27	0.29	0.30
	p-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	HML	0.58	0.52	0.45	0.57	0.49	0.38
	p-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	MOM	-0.05	-0.04	-0.05	-0.05	-0.03	-0.02
	p-value	(0.04)	(0.10)	(0.08)	(0.06)	(0.22)	(0.41)
	Adj-R^2 (%)	55	50	42	55	44	30

Panel B: Annual returns

		DCF valuations			*Decision-tree* valuations		
	CAP (yrs)	**10**	**20**	**30**	**10**	**20**	**30**
1 minus 10	Alpha (%)	5.92	7.14	7.28	5.76	8.16	7.83
	p-value	(0.15)	**(0.06)**	**(0.04)**	(0.15)	**(0.04)**	**(0.06)**
	SMB	0.60	0.56	0.44	0.60	0.52	0.44
	p-value	(0.05)	(0.04)	(0.07)	(0.04)	(0.06)	(0.13)
	HML	0.86	0.66	0.60	0.83	0.65	0.62
	p-value	(0.00)	(0.01)	(0.01)	(0.00)	(0.01)	(0.02)
	MOM	-0.20	-0.28	-0.26	-0.19	-0.34	-0.27
	p-value	(0.42)	(0.22)	(0.21)	(0.44)	(0.17)	(0.29)
	Adj-R^2 (%)	66	67	64	67	64	54
1-2 minus 9-10	Alpha (%)	4.34	3.69	4.36	4.51	4.60	4.48
	p-value	(0.15)	(0.22)	**(0.08)**	(0.14)	**(0.07)**	(0.11)
	SMB	0.58	0.50	0.35	0.61	0.51	0.39
	p-value	(0.01)	(0.02)	(0.05)	(0.01)	(0.01)	(0.05)
	HML	0.64	0.65	0.54	0.63	0.57	0.44
	p-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)
	MOM	-0.18	-0.16	-0.26	-0.18	-0.23	-0.25
	p-value	(0.33)	(0.37)	(0.09)	(0.34)	(0.13)	(0.15)
	Adj-R^2 (%)	73	70	73	73	78	64
1-3 minus 8-10	Alpha (%)	3.52	3.42	2.97	3.51	3.64	3.38
	p-value	(0.18)	(0.13)	(0.13)	(0.17)	**(0.08)**	(0.13)
	SMB	0.56	0.48	0.44	0.55	0.44	0.35
	p-value	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.03)
	HML	0.53	0.52	0.44	0.54	0.50	0.41
	p-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
	MOM	-0.16	-0.16	-0.13	-0.17	-0.19	-0.18
	p-value	(0.31)	(0.24)	(0.26)	(0.28)	(0.14)	(0.20)
	Adj-R^2 (%)	74	77	77	75	79	68

Table 2.17

Regression results – Sample partitioned into four sub-samples on the basis of size and the market-to-book ratio

In each year, I partitioned the sample into four equal-sized sub-samples according to size and the market-to-book equity ratio. First, in each year I formed two equal-sized groups after ranking stocks according to market-to-book equity. Second, within those groups, I ranked stocks according to market capitalisation. For each of the four sub-samples in each year, I ranked stocks according to value/price, where value is estimated using a *DCF* or *Decision-tree* valuation model, and share price is the closing price at 30 April. Table 2.17 presents the results of regression analysis where the dependent variable is returns to long-short portfolios formed on the basis of value relative to price. These portfolios are equally-weighted and comprise either the top and bottom 10, 20 or 30 percent of stocks according to this ranking. The independent variables are $R_m - R_f$ (the return to a value-weighted portfolio of all US-listed stocks minus the risk-free rate), *SMB* (the return to an equally-weighted portfolio of small stocks minus the return to an equally-weighted portfolio of big stocks), *HML* (the return to an equally-weighted portfolio of high book-to-market equity stocks minus the return to a portfolio of low market-to-book equity stocks), and *MOM* (the return to a an equally-weighted portfolio of stocks with high cumulative returns from 12 to 2 months prior to portfolio formation, minus the returns to an equally-weighted portfolio of stocks with low cumulative returns). The regressions are conducted using both monthly and annual returns. Hence, the regression model is: $\left(R_{long} - R_{short}\right)_i - R_{f,i} = \alpha + \beta\left(R_m - R_f\right)_i + sSMB_i + hHML_i + mMOM_i + \varepsilon_i$ where i refers to month 1 to 216 or year 1 to 18. In the regressions on annual returns, the market returns variable is omitted due to a general lack of statistical significance and its negative impact on explanatory power. The valuation models are summarised in Exhibits 2.2 and 2.9. The sample comprises 9427 firm-years from 1987-2004, representing 1049 individual stocks.

Panel A: Monthly returns

		(1) Small, low market-to-book						(2) Large, low market-to-book					
		DCF valuations			*Decision-tree* valns			*DCF* valuations			*Decision-tree* valns		
	CAP	**10**	**20**	**30**	**10**	**20**	**30**	**10**	**20**	**30**	**10**	**20**	**30**
1 minus 10	Alpha(%)	0.47	0.28	-0.09	0.49	0.32	0.21	0.35	0.23	0.36	0.40	0.26	0.39
	p-val	(0.23)	(0.46)	(0.81)	(0.22)	(0.37)	(0.53)	(0.29)	(0.46)	(0.22)	(0.20)	(0.35)	(0.16)
	Beta	-0.16	-0.05	-0.06	-0.14	-0.03	0.02	0.02	-0.01	-0.07	0.00	-0.04	-0.04
	p-val	(0.10)	(0.61)	(0.52)	(0.14)	(0.76)	(0.82)	(0.77)	(0.87)	(0.30)	(0.98)	(0.61)	(0.55)
	SMB	0.18	0.21	0.13	0.18	0.22	0.21	0.19	0.18	0.14	0.19	0.17	0.11
	p-val	(0.12)	(0.06)	(0.19)	(0.11)	(0.03)	(0.03)	(0.05)	(0.05)	(0.10)	(0.04)	(0.04)	(0.17)
	HML	0.20	0.32	0.25	0.16	0.24	0.13	0.40	0.35	0.26	0.39	0.27	0.23
	p-val	(0.16)	(0.02)	(0.05)	(0.26)	(0.07)	(0.30)	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)	(0.02)
	MOM	-0.07	-0.06	-0.11	-0.11	-0.09	-0.07	-0.15	-0.15	-0.12	-0.14	-0.14	-0.10
	p-val	(0.39)	(0.44)	(0.13)	(0.16)	(0.24)	(0.33)	(0.03)	(0.02)	(0.05)	(0.03)	(0.01)	(0.07)
	A-R^2(%)	3	3	2	2	2	1	6	6	5	7	6	4
1-2 minus 9-10	Alpha(%)	0.20	0.13	0.15	0.18	0.07	0.01	0.12	0.16	0.10	0.17	0.12	0.14
	p-val	(0.45)	(0.61)	(0.56)	(0.47)	(0.76)	(0.98)	(0.60)	(0.46)	(0.63)	(0.44)	(0.59)	(0.54)
	Beta	-0.15	-0.10	-0.07	-0.13	-0.03	-0.01	-0.03	-0.04	-0.02	-0.01	0.02	0.05
	p-val	(0.02)	(0.12)	(0.28)	(0.03)	(0.66)	(0.89)	(0.59)	(0.45)	(0.67)	(0.80)	(0.71)	(0.31)
	SMB	0.07	0.07	0.03	0.10	0.08	0.10	0.14	0.15	0.11	0.14	0.16	0.18
	p-val	(0.36)	(0.37)	(0.66)	(0.15)	(0.25)	(0.18)	(0.03)	(0.02)	(0.09)	(0.02)	(0.01)	(0.01)
	HML	0.23	0.20	0.20	0.25	0.21	0.14	0.37	0.31	0.28	0.34	0.31	0.22
	p-val	(0.02)	(0.04)	(0.04)	(0.01)	(0.02)	(0.12)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
	MOM	0.01	-0.02	0.02	0.01	-0.02	-0.05	-0.05	-0.06	-0.08	-0.08	-0.11	-0.13
	p-val	(0.90)	(0.75)	(0.70)	(0.84)	(0.67)	(0.29)	(0.23)	(0.13)	(0.07)	(0.07)	(0.02)	(0.00)
	A-R^2(%)	8	4	3	8	2	0	11	10	7	10	8	7
1-3 minus 8-10	Alpha(%)	0.26	0.16	0.18	0.24	0.20	0.06	0.15	0.14	0.13	0.16	0.12	0.15
	p-value	(0.24)	(0.44)	(0.36)	(0.26)	(0.34)	(0.74)	(0.38)	(0.44)	(0.48)	(0.36)	(0.51)	(0.40)
	Beta	-0.14	-0.12	-0.09	-0.13	-0.08	-0.02	-0.05	-0.07	-0.05	-0.04	0.02	0.01
	p-value	(0.01)	(0.02)	(0.06)	(0.02)	(0.12)	(0.69)	(0.24)	(0.13)	(0.24)	(0.36)	(0.67)	(0.77)
	SMB	0.06	0.02	0.03	0.09	0.12	0.11	0.12	0.09	0.09	0.15	0.15	0.13
	p-value	(0.37)	(0.73)	(0.57)	(0.15)	(0.04)	(0.04)	(0.02)	(0.08)	(0.09)	(0.00)	(0.00)	(0.01)
	HML	0.14	0.13	0.15	0.19	0.16	0.11	0.29	0.27	0.25	0.31	0.29	0.19
	p-value	(0.08)	(0.08)	(0.04)	(0.02)	(0.03)	(0.10)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	MOM	-0.01	-0.02	-0.01	0.00	-0.03	-0.07	-0.06	-0.06	-0.06	-0.05	-0.06	-0.11
	p-value	(0.84)	(0.71)	(0.89)	(0.95)	(0.54)	(0.08)	(0.07)	(0.12)	(0.12)	(0.14)	(0.07)	(0.00)
	A-R^2(%)	6	6	5	8	4	2	13	12	10	14	10	7

		(3) Small, high market-to-book						(4) Large, high market-to-book					
		DCF valuations			*Decision-tree* valns			*DCF* valuations			*Decision-tree* valns		
	CAP	**10**	**20**	**30**	**10**	**20**	**30**	**10**	**20**	**30**	**10**	**20**	**30**
1 minus 10	Alpha(%)	0.79	0.51	0.50	0.76	0.67	0.38	-0.22	-0.20	-0.06	-0.30	-0.07	-0.13
	p-value	**(0.06)**	(0.23)	(0.22)	**(0.06)**	**(0.09)**	(0.36)	(0.46)	(0.50)	(0.84)	(0.34)	(0.80)	(0.63)
	Beta	-0.27	-0.27	-0.16	-0.25	-0.16	-0.05	-0.11	-0.04	0.00	-0.12	-0.02	0.06
	p-value	(0.01)	(0.01)	(0.09)	(0.01)	(0.09)	(0.60)	(0.13)	(0.58)	(0.99)	(0.11)	(0.82)	(0.39)
	SMB	0.18	0.24	0.21	0.16	0.22	0.21	0.08	0.02	-0.04	0.11	0.03	0.00
	p-value	(0.12)	(0.05)	(0.07)	(0.16)	(0.05)	(0.08)	(0.35)	(0.77)	(0.66)	(0.24)	(0.75)	(0.96)
	HML	0.76	0.64	0.52	0.76	0.49	0.43	0.81	0.63	0.49	0.91	0.58	0.39
	p-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	MOM	-0.29	-0.22	-0.19	-0.25	-0.28	-0.17	0.02	0.04	0.04	0.07	0.03	-0.01
	p-value	(0.00)	(0.01)	(0.02)	(0.00)	(0.00)	(0.04)	(0.75)	(0.54)	(0.45)	(0.31)	(0.56)	(0.92)
	A-R^2 (%)	23	17	11	23	13	6	30	19	14	32	17	7
1-2 minus 9-10	Alpha(%)	0.16	0.31	0.27	0.25	0.38	0.52	-0.13	-0.11	-0.05	-0.23	-0.15	0.06
	p-value	(0.58)	(0.28)	(0.35)	(0.36)	(0.16)	**(0.05)**	(0.54)	(0.60)	(0.83)	(0.29)	(0.51)	(0.77)
	Beta	-0.24	-0.20	-0.13	-0.23	-0.15	-0.05	-0.06	-0.04	-0.08	-0.04	-0.02	-0.03
	p-value	(0.00)	(0.00)	(0.06)	(0.00)	(0.03)	(0.45)	(0.25)	(0.41)	(0.14)	(0.40)	(0.71)	(0.63)
	SMB	0.21	0.16	0.14	0.16	0.16	0.12	0.10	0.07	0.06	0.08	0.12	0.09
	p-value	(0.01)	(0.05)	(0.08)	(0.05)	(0.04)	(0.11)	(0.08)	(0.23)	(0.38)	(0.17)	(0.08)	(0.16)
	HML	0.57	0.48	0.41	0.48	0.46	0.28	0.62	0.50	0.43	0.64	0.50	0.36
	p-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	MOM	-0.16	-0.16	-0.13	-0.13	-0.15	-0.02	0.05	0.00	0.02	0.03	0.05	-0.01
	p-value	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)	(0.64)	(0.29)	(0.92)	(0.64)	(0.43)	(0.30)	(0.88)
	A-R^2 (%)	25	21	14	23	18	4	32	22	18	31	18	11
1-3 minus 8-10	Alpha(%)	0.24	0.21	0.34	0.31	0.24	0.27	-0.06	-0.08	-0.18	-0.05	-0.10	-0.03
	p-value	(0.28)	(0.33)	(0.12)	(0.13)	(0.24)	(0.21)	(0.72)	(0.66)	(0.34)	(0.74)	(0.57)	(0.88)
	Beta	-0.16	-0.12	-0.09	-0.17	-0.07	0.01	-0.09	-0.10	-0.07	-0.09	-0.05	-0.02
	p-value	(0.00)	(0.03)	(0.10)	(0.00)	(0.13)	(0.81)	(0.02)	(0.02)	(0.11)	(0.03)	(0.20)	(0.58)
	SMB	0.12	0.09	0.09	0.12	0.12	0.13	0.04	0.04	0.05	0.05	0.05	0.08
	p-value	(0.06)	(0.13)	(0.14)	(0.04)	(0.05)	(0.04)	(0.38)	(0.45)	(0.39)	(0.29)	(0.34)	(0.11)
	HML	0.50	0.41	0.31	0.45	0.32	0.19	0.47	0.40	0.39	0.48	0.39	0.26
	p-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	MOM	-0.16	-0.11	-0.09	-0.11	-0.01	0.02	0.01	0.01	0.01	0.01	0.00	-0.01
	p-value	(0.00)	(0.01)	(0.05)	(0.01)	(0.81)	(0.70)	(0.86)	(0.76)	(0.87)	(0.72)	(0.98)	(0.70)
	A-R^2(%)	29	21	12	30	12	2	34	27	21	35	23	8

Panel B: Annual returns

		(1) Small, low market-to-book						(2) Large, low market-to-book					
		***DCF* valuations**			***Decision-tree* valns**			***DCF* valuations**			***Decision-tree* valns**		
	CAP (yrs)	**10**	**20**	**30**	**10**	**20**	**30**	**10**	**20**	**30**	**10**	**20**	**30**
1 minus 10	Alpha (%)	10.70	8.81	5.64	10.69	8.97	5.16	7.77	5.80	6.90	8.50	5.87	6.16
	p-value	**(0.08)**	(0.12)	(0.26)	**(0.09)**	**(0.06)**	(0.33)	(0.16)	(0.23)	(0.12)	**(0.10)**	(0.16)	(0.16)
	SMB	0.71	1.02	0.75	0.74	0.81	0.46	0.36	0.32	0.38	0.35	0.37	0.22
	p-value	(0.10)	(0.01)	(0.04)	(0.09)	(0.02)	(0.22)	(0.34)	(0.34)	(0.21)	(0.31)	(0.19)	(0.47)
	HML	-0.64	-0.44	-0.56	-0.75	-0.53	-0.30	0.41	0.43	0.35	0.32	0.26	0.36
	p-value	(0.10)	(0.21)	(0.08)	(0.06)	(0.08)	(0.37)	(0.23)	(0.16)	(0.20)	(0.30)	(0.30)	(0.19)
	MOM	-0.09	-0.03	-0.23	-0.05	-0.06	-0.03	-0.47	-0.48	-0.41	-0.44	-0.38	-0.32
	p-value	(0.81)	(0.93)	(0.45)	(0.90)	(0.84)	(0.93)	(0.18)	(0.12)	(0.14)	(0.16)	(0.14)	(0.24)
	Adj-R^2 (%)	13	29	27	16	29	-4	32	40	41	32	39	27
1-2 minus 9-10	Alpha (%)	2.77	3.82	4.43	3.14	3.19	4.91	4.27	4.32	4.02	5.08	3.50	3.76
	p-value	(0.52)	(0.34)	(0.31)	(0.44)	(0.35)	(0.20)	(0.20)	(0.14)	(0.19)	(0.14)	(0.27)	(0.21)
	SMB	0.78	0.62	0.66	0.71	0.66	0.56	0.27	0.23	0.19	0.21	0.08	0.02
	p-value	(0.02)	(0.04)	(0.04)	(0.02)	(0.01)	(0.05)	(0.24)	(0.25)	(0.36)	(0.38)	(0.73)	(0.91)
	HML	-0.12	-0.24	-0.30	-0.18	-0.20	-0.41	0.34	0.31	0.23	0.35	0.39	0.27
	p-value	(0.66)	(0.35)	(0.27)	(0.47)	(0.34)	(0.10)	(0.11)	(0.10)	(0.23)	(0.11)	(0.06)	(0.15)
	MOM	0.26	0.08	0.15	0.23	0.10	-0.14	-0.32	-0.31	-0.33	-0.40	-0.37	-0.39
	p-value	(0.35)	(0.76)	(0.58)	(0.36)	(0.63)	(0.55)	(0.13)	(0.09)	(0.00)	(0.07)	(0.07)	(0.05)
	Adj-R^2 (%)	20	15	13	18	25	23	45	48	39	46	43	37
1-3 minus 8-10	Alpha (%)	3.47	2.52	2.60	3.39	3.43	2.66	4.36	4.05	3.94	4.72	4.13	4.20
	p-value	(0.37)	(0.43)	(0.40)	(0.34)	(0.28)	(0.27)	**(0.08)**	**(0.09)**	**(0.10)**	**(0.06)**	**(0.07)**	**(0.05)**
	SMB	0.42	0.49	0.50	0.41	0.54	0.50	0.19	0.13	0.09	0.16	0.09	-0.07
	p-value	(0.13)	(0.04)	(0.03)	(0.11)	(0.02)	(0.01)	(0.27)	(0.41)	(0.57)	(0.33)	(0.55)	(0.61)
	HML	-0.01	-0.05	-0.01	0.11	-0.03	-0.14	0.19	0.19	0.17	0.22	0.21	0.17
	p-value	(0.97)	(0.80)	(0.97)	(0.63)	(0.86)	(0.36)	(0.22)	(0.21)	(0.23)	(0.16)	(0.14)	(0.18)
	MOM	0.05	0.08	0.11	0.01	0.04	-0.04	-0.29	-0.29	-0.30	-0.31	-0.31	-0.39
	p-value	(0.83)	(0.68)	(0.56)	(0.98)	(0.85)	(0.79)	(0.07)	(0.06)	(0.05)	(0.05)	(0.03)	(0.01)
	Adj-R^2 (%)	1	15	18	13	24	37	45	42	39	48	47	47

		(3) Small, high market-to-book						(4) Large, high market-to-book					
		***DCF* valuations**			***Decision-tree* valns**			***DCF* valuations**			***Decision-tree* valns**		
	CAP (yrs)	**10**	**20**	**30**	**10**	**20**	**30**	**10**	**20**	**30**	**10**	**20**	**30**
1 minus 10	Alpha (%)	12.16	9.24	7.52	10.54	9.22	7.18	-5.73	-4.40	-4.42	-6.72	-3.06	-4.59
	p-value	(0.14)	(0.23)	(0.19)	(0.15)	**(0.06)**	(0.12)	(0.37)	(0.39)	(0.44)	(0.29)	(0.60)	(0.43)
	SMB	0.16	-0.31	-0.42	-0.02	-0.19	-0.23	-0.10	-0.53	-0.43	-0.15	-0.55	-0.73
	p-value	(0.77)	(0.55)	(0.29)	(0.97)	(0.56)	(0.45)	(0.82)	(0.15)	(0.28)	(0.73)	(0.19)	(0.08)
	HML	0.84	0.83	0.64	0.98	0.81	0.74	1.22	1.14	1.05	1.31	1.11	0.95
	p-value	(0.11)	(0.09)	(0.08)	(0.04)	(0.01)	(0.02)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.02)
	MOM	-0.76	-0.94	-0.67	-0.69	-0.77	-0.76	0.00	-0.20	0.03	0.03	-0.19	-0.16
	p-value	(0.14)	(0.06)	(0.07)	(0.14)	(0.02)	(0.01)	(0.99)	(0.52)	(0.94)	(0.94)	(0.60)	(0.66)
	Adj-R^2 (%)	32	32	27	36	54	53	33	42	27	36	32	26
1-2 minus 9-10	Alpha (%)	3.11	5.53	5.15	4.09	5.99	8.02	-3.27	-2.34	-2.78	-3.86	-3.32	-1.50
	p-value	(0.61)	(0.26)	(0.24)	(0.44)	(0.12)	**(0.02)**	(0.43)	(0.60)	(0.53)	(0.40)	(0.49)	(0.73)
	SMB	0.09	-0.03	-0.06	-0.06	0.03	-0.33	-0.04	-0.19	-0.16	-0.19	-0.36	-0.29
	p-value	(0.83)	(0.93)	(0.83)	(0.86)	(0.91)	(0.14)	(0.88)	(0.55)	(0.61)	(0.56)	(0.30)	(0.34)
	HML	0.81	0.65	0.71	0.70	0.57	0.53	0.85	0.67	0.64	0.86	0.84	0.64
	p-value	(0.05)	(0.05)	(0.02)	(0.05)	(0.02)	(0.02)	(0.00)	(0.03)	(0.03)	(0.01)	(0.01)	(0.03)
	MOM	-0.57	-0.60	-0.63	-0.55	-0.47	-0.50	0.03	-0.08	0.04	-0.07	-0.12	-0.03
	p-value	(0.15)	(0.06)	(0.03)	(0.11)	(0.05)	(0.02)	(0.90)	(0.79)	(0.89)	(0.81)	(0.70)	(0.90)
	Adj-R^2 (%)	36	42	53	35	50	47	37	17	15	31	26	15
1-3 minus 8-10	Alpha (%)	3.66	2.59	4.07	4.46	3.49	5.03	-1.38	-2.40	-3.78	-1.35	-1.77	-1.37
	p-value	(0.47)	(0.50)	(0.24)	(0.28)	(0.24)	**(0.05)**	(0.67)	(0.45)	(0.34)	(0.69)	(0.60)	(0.72)
	SMB	0.15	0.04	-0.07	0.05	-0.12	-0.20	-0.05	-0.04	-0.12	-0.07	-0.12	-0.28
	p-value	(0.67)	(0.87)	(0.76)	(0.85)	(0.55)	(0.23)	(0.83)	(0.85)	(0.65)	(0.76)	(0.61)	(0.31)
	HML	0.55	0.61	0.58	0.51	0.50	0.31	0.53	0.53	0.54	0.58	0.48	0.39
	p-value	(0.09)	(0.02)	(0.02)	(0.06)	(0.01)	(0.05)	(0.02)	(0.02)	(0.04)	(0.01)	(0.03)	(0.12)
	MOM	-0.34	-0.30	-0.31	-0.33	-0.28	-0.32	-0.04	0.02	0.01	-0.05	-0.06	-0.09
	p-value	(0.28)	(0.22)	(0.16)	(0.20)	(0.14)	(0.04)	(0.86)	(0.92)	(0.96)	(0.82)	(0.78)	(0.72)
	Adj-R^2 (%)	27	40	40	32	40	35	24	24	12	27	16	2

Table 2.18
Regression results for high- and low-growth industries

I partitioned the sample into two sub-samples based on initial growth rates for the stocks' IBES industry sectors. High-growth sectors are Technology, Healthcare and Consumer Services and low-growth sectors are Basic industries, Capital goods, Consumer durables, Consumer non-durables, Energy, Finance, Transport and Utilities. Table 2.18 presents the results of regression analysis where the dependent variable is returns to long-short portfolios formed on the basis of value relative to price. These portfolios are equally-weighted and comprise either the top and bottom 10, 20 or 30 percent of stocks according to this ranking. The independent variables are $R_m - R_f$ (the return to a value-weighted portfolio of all US-listed stocks minus the risk-free rate), *SMB* (the return to an equally-weighted portfolio of small stocks minus the return to an equally-weighted portfolio of big stocks), *HML* (the return to an equally-weighted portfolio of high book-to-market equity stocks minus the return to a portfolio of low market-to-book equity stocks), and *MOM* (the return to a an equally-weighted portfolio of stocks with high cumulative returns from 12 to 2 months prior to portfolio formation, minus the returns to an equally-weighted portfolio of stocks with low cumulative returns). The regressions are conducted using both monthly and annual returns. Hence, the regression model is: $(R_{long} - R_{short})_i - R_{f,i} = \alpha + \beta(R_m - R_f)_i + sSMB_i + hHML_i + mMOM_i + \varepsilon_i$ where i refers to month 1 to 216 or year 1 to 18. In the regressions on annual returns, the market returns variable is omitted due to a general lack of statistical significance and its negative impact on explanatory power. The valuation models are summarised in Exhibits 2.2 and 2.9. The sample comprises 9427 firm-years from 1987-2004, representing 1049 individual stocks.

Panel A: Monthly returns

		(1) High growth industries						(2) Low-growth industries					
		DCF valuations			*Decision-tree* valns			*DCF* valuations			*Decision-tree* valns		
	CAP (yrs)	10	20	30	10	20	30	10	20	30	10	20	30
1 minus 10	Alpha(%)	0.45	0.51	0.57	0.33	0.55	0.69	0.46	0.28	0.24	0.41	0.30	0.36
	p-value	(0.23)	(0.16)	(0.11)	(0.37)	(0.11)	**(0.05)**	**(0.04)**	(0.18)	(0.21)	**(0.06)**	(0.16)	**(0.09)**
	Beta	-0.19	-0.22	-0.20	-0.16	-0.19	-0.13	-0.09	-0.12	-0.12	-0.09	-0.10	-0.07
	p-value	(0.03)	(0.01)	(0.02)	(0.07)	(0.02)	(0.13)	(0.10)	(0.02)	(0.01)	(0.09)	(0.05)	(0.16)
	SMB	0.53	0.49	0.52	0.59	0.54	0.55	0.22	0.18	0.16	0.21	0.21	0.27
	p-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	HML	1.08	0.90	0.85	1.15	0.84	0.71	0.35	0.32	0.30	0.36	0.36	0.35
	p-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	MOM	-0.10	-0.07	-0.06	-0.05	-0.03	-0.04	-0.16	-0.18	-0.16	-0.17	-0.14	-0.17
	p-value	(0.17)	(0.37)	(0.40)	(0.51)	(0.67)	(0.55)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	A-R^2 (%)	33	28	26	35	27	21	17	20	20	19	19	19
1-2 minus 9-10	Alpha(%)	0.43	0.26	0.31	0.40	0.26	0.22	0.26	0.25	0.17	0.26	0.19	0.11
	p-value	(0.11)	(0.35)	(0.25)	(0.13)	(0.33)	(0.43)	(0.12)	(0.13)	(0.30)	(0.12)	(0.24)	(0.52)
	Beta	-0.14	-0.07	-0.07	-0.13	-0.07	-0.03	-0.13	-0.12	-0.07	-0.11	-0.05	-0.01
	p-value	(0.04)	(0.29)	(0.31)	(0.04)	(0.26)	(0.64)	(0.00)	(0.00)	(0.06)	(0.01)	(0.22)	(0.88)
	SMB	0.51	0.47	0.41	0.51	0.50	0.51	0.18	0.19	0.18	0.21	0.23	0.24
	p-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	HML	0.86	0.82	0.68	0.90	0.81	0.68	0.28	0.28	0.27	0.30	0.33	0.31
	p-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	MOM	-0.11	-0.11	-0.06	-0.12	-0.07	-0.01	-0.09	-0.09	-0.10	-0.09	-0.09	-0.08
	p-value	(0.05)	(0.05)	(0.28)	(0.03)	(0.20)	(0.90)	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)
	A-R^2 (%)	37	32	25	40	32	25	22	21	18	23	22	18
1-3 minus 8-10	Alpha(%)	0.19	0.16	0.17	0.15	0.13	0.17	0.18	0.20	0.12	0.18	0.14	0.11
	p-value	(0.38)	(0.44)	(0.43)	(0.50)	(0.53)	(0.42)	(0.21)	(0.15)	(0.39)	(0.20)	(0.32)	(0.43)
	Beta	-0.06	-0.02	-0.02	-0.05	0.01	0.03	-0.13	-0.12	-0.10	-0.13	-0.07	-0.04
	p-value	(0.23)	(0.68)	(0.68)	(0.38)	(0.81)	(0.61)	(0.00)	(0.00)	(0.00)	(0.00)	(0.05)	(0.22)
	SMB	0.44	0.43	0.39	0.46	0.47	0.42	0.20	0.16	0.15	0.19	0.22	0.23
	p-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	HML	0.80	0.76	0.64	0.81	0.73	0.58	0.26	0.21	0.20	0.26	0.25	0.22
	p-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	MOM	-0.10	-0.08	-0.09	-0.08	-0.07	-0.03	-0.06	-0.07	-0.09	-0.07	-0.07	-0.07
	p-value	(0.02)	(0.07)	(0.04)	(0.06)	(0.09)	(0.49)	(0.03)	(0.01)	(0.00)	(0.01)	(0.01)	(0.02)
	A-R^2 (%)	41	38	31	42	37	27	26	22	20	27	22	19

Panel B: Annual returns

1 minus 10	Alpha(%)	7.01	8.37	8.28	6.30	9.54	11.49	1.97	0.14	0.03	1.23	0.31	2.92
	p-value	(0.23)	(0.16)	(0.16)	(0.27)	(0.12)	**(0.05)**	(0.57)	(0.97)	(0.99)	(0.75)	(0.93)	(0.50)
	SMB	0.81	0.75	0.63	0.90	0.80	0.68	0.54	0.53	0.41	0.52	0.44	0.38
	p-value	(0.05)	(0.07)	(0.12)	(0.03)	(0.06)	(0.08)	(0.04)	(0.04)	(0.10)	(0.06)	(0.10)	(0.21)
	HML	1.03	0.90	0.84	1.14	0.90	0.84	0.30	0.26	0.34	0.34	0.36	0.33
	p-value	(0.01)	(0.03)	(0.03)	(0.01)	(0.03)	(0.03)	(0.19)	(0.23)	(0.14)	(0.18)	(0.14)	(0.24)
	MOM	-0.30	-0.38	-0.30	-0.32	-0.45	-0.52	0.31	0.24	0.14	0.30	0.23	-0.01
	p-value	(0.43)	(0.34)	(0.44)	(0.41)	(0.26)	(0.17)	(0.20)	(0.31)	(0.54)	(0.26)	(0.38)	(0.97)
	A-R^2 (%)	58	52	46	63	55	55	32	30	25	27	25	14
1-2 minus 9-10	Alpha(%)	5.44	2.32	4.91	4.54	4.12	4.05	0.71	1.57	1.05	0.88	1.47	0.64
	p-value	(0.22)	(0.57)	(0.23)	(0.29)	(0.27)	(0.29)	(0.77)	(0.55)	(0.69)	(0.74)	(0.61)	(0.83)
	SMB	1.10	0.90	0.66	0.99	0.92	0.84	0.50	0.44	0.36	0.48	0.39	0.30
	p-value	(0.00)	(0.01)	(0.03)	(0.00)	(0.00)	(0.00)	(0.01)	(0.03)	(0.06)	(0.02)	(0.07)	(0.17)
	HML	0.80	0.97	0.86	0.95	0.79	0.73	0.23	0.20	0.19	0.24	0.25	0.22
	p-value	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.16)	(0.23)	(0.25)	(0.16)	(0.19)	(0.26)
	MOM	-0.02	-0.04	-0.27	-0.06	-0.10	-0.13	0.22	0.11	0.06	0.21	0.06	0.05
	p-value	(0.94)	(0.89)	(0.34)	(0.83)	(0.68)	(0.61)	(0.21)	(0.52)	(0.72)	(0.25)	(0.76)	(0.82)
	A-R^2 (%)	69	72	66	72	73	69	45	35	27	40	28	14
1-3 minus 8-10	Alpha(%)	2.10	1.40	1.69	1.93	2.27	2.80	0.47	0.90	0.56	0.53	0.54	0.99
	p-value	(0.59)	(0.71)	(0.66)	(0.61)	(0.49)	(0.39)	(0.84)	(0.68)	(0.78)	(0.82)	(0.82)	(0.70)
	SMB	0.88	0.76	0.78	0.88	0.90	0.77	0.51	0.42	0.32	0.51	0.34	0.29
	p-value	(0.00)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.04)	(0.01)	(0.06)	(0.11)
	HML	0.85	0.86	0.70	0.89	0.77	0.60	0.20	0.18	0.15	0.21	0.25	0.23
	p-value	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.01)	(0.20)	(0.19)	(0.25)	(0.18)	(0.12)	(0.18)
	MOM	-0.03	0.00	0.01	-0.06	-0.05	-0.01	0.17	0.12	0.03	0.15	0.05	-0.04
	p-value	(0.92)	(1.00)	(0.96)	(0.82)	(0.81)	(0.95)	(0.29)	(0.43)	(0.85)	(0.36)	(0.74)	(0.82)
	A-R^2 (%)	70	68	63	72	77	69	46	42	33	48	34	28

5.3 Association between credit ratings and firm characteristics

In this section, I measure the association between credit ratings and firm characteristics which could explain the relatively high returns of small, low market-to-books stocks. Recall that the difference between the mean returns to decile 1 stocks, compared to decile 10 stocks, is around 6.9-7.5 percent, and the difference in mean Sharpe ratios is around 0.4. Say we assume that, for whatever reason, the regression analysis does not adequately control for risk. The issue remains, can we place some reasonable bounds on the incremental returns investors demand as compensation for the risk of these stocks?

The analysis presented in this section provides some evidence that the incremental returns to small stocks are due to the increased risk of distress. But there is limited evidence that the market-to-book ratio captures the risk of distress. This evidence suggests that the outperformance of portfolios formed from fundamental analysis cannot be attributed to the greater risk of these portfolios.

To this point, the data is consistent with the following conclusions:

1. An investment strategy which relies on valuations which assume revenue growth and profit margins revert to long-term sustainable levels is associated with above-average returns.
2. The stocks selected as relatively undervalued are predominantly small, low-market-to-book stocks, but the preference towards low market-to-book stocks is reduced once the assumed competitive advantage period is increased.
3. Portfolios formed from this strategy have above-average volatility, but their reward-for-risk remains significantly positive, as measured by the Sharpe ratio.
4. There remains evidence of outperformance after controlling for factors associated with stocks returns – market risk, size, the book-to-market ratio and momentum. This evidence is in the form of significantly positive intercept terms from linear regressions of returns to long-short investment portfolios on four explanatory factors.
5. Positive risk-adjusted performance is most consistent amongst small, high market-to-book stocks and there is no evidence of outperformance amongst large, high market-to-book stocks, which form the major component of investment manager portfolios.

However, there remains the possibility that portfolios formed from stocks identified as being undervalued were indeed riskier than the rest of the market and that this has not been adequately controlled for. One reason this could occur is survivorship bias. The sample was drawn from stocks which formed part of the S&P500 or NASDAQ Composite Index at 30 April 2004. If there were a number of stocks identified as undervalued which went bankrupt during the sample period measured performance would have been substantially worse. By the same token, if there were a number of stocks identified as undervalued which were taken over during the sample period, measured performance would have been substantially better. In addition, I only investigated stocks in which analyst earnings forecasts were available. Analysts often cease coverage of stocks they expect to perform particularly badly. For example, the House Committee of Financial Services investigated the analyst research on 21 poorly-performing companies covered by Goldman Sachs, Credit Suisse First Boston and Citigroup/Salomon Smith Barney during 1999-2000. None of the firms issued sell recommendations, but Goldman Sachs and Citigroup/Salomon Smith Barney ceased coverage of most stocks (Oxley, 2002). Therefore, the database is likely to be biased towards stocks in which analysts have positive expectations. If these unobservable stocks were identified as undervalued by the models, under the assumption that their growth and margins would recover, and they performed particularly poorly during the sample period, measured performance would have declined.

So, we know that the fundamental valuation models identify small, low market-to-book stocks as relatively undervalued and portfolios of these stocks earn higher returns. But there remains the possibility that this is due to some unspecified risk factor. The most plausible risk factor is the risk of financial distress. To assess the likely impact of this risk on required returns to equityholders I turn to the debt market, in which required returns are more readily observable.

For the 5,557 firm-years in which a Standard and Poors credit rating was available, I measure the association between credit ratings and the following variables – probability of negative earnings, equity beta, market capitalisation and the market-to-book equity ratio. I estimated the mean probability of negative earnings as estimated by the *Decision-tree* valuation model, assuming a competitive advantage of 10 years. This is measured as the percentage of years in which simulated earnings were negative. The results of the 10-year *CAP* simulation were used in this case because the probability of negative earnings diminishes over later-year simulations, as simulated parameter values approach long-term estimates. I ignored '+' and '-' variations to the credit ratings to increase sample size within each rating.

In Table 2.19 I present the percentage of firms within each credit rating by cohort year and for the pooled sample. I also present the mean estimates of the four variables listed above and perform two-sample *t*-tests for a difference in means as credit rating diminishes. Referring to the pooled data on negative earnings we see that 5.4 percent of simulated earnings were negative. As a reference point, 7.0 percent of actual year 0 earnings were negative for the full sample. Considering that long-term margins are positive, to observe negative earnings in 5.4 percent of cases in the first 10 years appears reasonable. We also see a consistent association between the probability of negative earnings and credit rating. Firms rated AA had a 4.2 percent probability of negative earnings, which was significantly lower than the 4.9 percent probability for A-rated firms, and the 6.0 percent probability for BBB-rated firms. Investment-grade firms had a 5.1 percent probability of negative earnings, compared to 7.6 percent for the 12-percent of firms rated as non-investment grade.

Of the other firm characteristics, market capitalisation is the only variable which has a consistent association with credit ratings across all ratings classes. This association is also maintained in every year for almost all ratings classes. Thus, there is clear evidence that size is associated with increased default risk. But the association between credit ratings and the other variables – equity beta and the market-to-boo equity ratio – is not as strong. For the pooled sample, there is no significant difference between the mean market capitalisation amongst investment-grade and non-investment grade firms. Furthermore, the average market-to-book ratio of BB-rated firms (4.6) is significantly larger than the average ratio for BBB-rated firms (3.4). In general, there is an association between credit ratings and mean equity beta. Investment-grade firms have a mean beta estimate of 0.99, which is significantly lower than the mean estimate of 1.19 for non investment-grade firms. But there is one anomaly, in that BBB-rated firms had a significantly lower mean equity beta than A-rated firms.

I also measured how well these variables predict credit ratings. In each year, I ranked firms according to the variables and assigned synthetic credit ratings based on the distribution of actual credit ratings in each year. Then, I computed the proportion of ratings that were correct and compared the proportion to what would be expected under random assignment. These results are presented in Table 2.20. Market capitalisation clearly has the highest predictive ability. For the full sample, ranking by size correctly predicted 44.7 percent of credit ratings, compared to a naïve expectation of 28.0 percent. If we class a synthetic credit rating as 'correct' if it is within one rating either side of the actual rating, 91.1 percent of ratings based on size are correct, compared to a naïve expectation of 69.6 percent. In contrast, while the market-to-book equity ratio predicts significantly more credit ratings correctly than random assignment, the results are not nearly as strong. Just 34.9 percent of ratings are correctly predicted.

Table 2.19
Association between credit ratings and firm characteristics associated with default risk

Table 2.19 presents mean estimates of variables associated with long-term credit ratings assigned by Standard and Poors. The variables are: 1) the probability of negative earnings between the end of the explicit forecast period and the end of the competitive advantage period, assumed to be 10 years; 2) the estimated equity beta; 3) market capitalisation; and 4) the market-to-book equity ratio. The sample comprises 5,557 firm-years in which credit ratings were available, which represents 59 percent of the total sample. The proportion of the sample represented ranges from 50 percent in 2003 to 73 percent in 1996. *t*-tests have been conducted for the difference in means between adjacent ratings groups, e.g. A versus BBB, and between the sample of investment-grade and non-investment-grade bonds (***, ** and * refer to statistical significance at the 1, 5 and 10 percent level, respectively). Investment-grade bonds are those rated BBB and above. The row labelled "S&P" presents the average number of defaults by ratings class over 15 years from the time of rating, as estimated by Standard and Poors using data from 1981-2004. For example, of the bonds rated AAA at the start of the 15-year period, 0.6 percent are expected to default at some point during that interval. A default is recorded upon the incidence of one missed or delayed payment to a debtholder, which does not necessarily represent bankruptcy.

Rating	AAA		AA		A		BBB		BB		B	Inv grade		Non-inv	All
Def prob	***0.6***		***1.4***		***3.0***		***8.7***		***22.9***		***38.6***	***4.3***		***27.2***	***7.07***
Percentage of firms within each rating class															
1987	6		31		45		12		5		1	94		6	100
1988	7		29		45		13		5		3	93		7	100
1989	7		26		45		15		4		2	94		6	100
1990	7		25		43		18		6		2	92		8	100
1991	6		23		43		20		6		1	93		7	100
1992	6		23		44		21		6		1	92		8	100
1993	5		23		44		22		5		1	94		6	100
1994	5		22		45		21		6		0	93		7	100
1995	4		20		47		22		7		1	93		7	100
1996	5		18		48		22		6		1	93		7	100
1997	3		18		45		24		7		3	91		9	100
1998	3		15		46		24		8		4	89		11	100
1999	3		13		45		27		7		4	89		11	100
2000	3		12		41		30		11		3	86		14	100
2001	2		10		40		32		11		5	85		15	100
2002	3		8		36		35		13		5	82		18	100
2003	2		6		35		36		14		7	79		21	100
2004	2		6		34		35		15		8	77		23	100
Pooled	**4**		**16**		**42**		**26**		**9**		**3**	**88**		**12**	**100**
Mean probability of negative earnings between the end of the explicit forecast period and forecast year 10															
1987	2.5		2.8		2.8		3.2		4.5		3.2	2.8	***	4.2	2.9
1988	4.0		4.3		3.9		6.1		9.2		3.6	4.4		7.2	4.6
1989	5.0		5.5		5.6		6.6		12.1		5.0	5.7		9.9	6.0
1990	3.1		2.7		3.0	*	3.6		4.4		4.2	3.0	**	4.4	3.1
1991	2.0	***	2.4	***	2.7		3.0		3.6		3.9	2.7	***	3.6	2.7
1992	3.8		5.3	**	7.8		7.2	*	12.9	***	3.4	6.8	*	11.3	7.2
1993	4.6		4.3	*	5.9		7.7	***	3.8		3.9	5.8	***	3.8	5.7
1994	7.4	*	5.1		5.9		5.2		5.1		5.6	5.6		5.1	5.6
1995	2.8		4.3		3.6	*	4.6		4.9		5.4	4.0		5.0	4.0
1996	2.9		3.0		3.5	**	4.7		4.1		6.5	3.7		4.6	3.7
1997	2.4		2.5		2.7	***	3.5		3.3	**	4.7	2.9	**	3.7	2.9
1998	1.8	***	4.3		4.0		4.0		4.2		4.7	4.0		4.4	4.0
1999	3.0		4.3		4.4	***	6.9		5.1	*	9.2	5.1		6.5	5.3
2000	2.6		2.6		2.9		3.0	***	4.1		3.2	2.9	***	3.9	3.0
2001	5.0	*	3.3		3.8	***	4.7	**	6.1		6.7	4.1	***	6.3	4.5
2002	2.3		3.5	*	5.5		6.8		8.1		5.4	5.8		7.3	6.0
2003	6.2		7.2		7.0		7.9		8.5		11.1	7.4	**	9.3	7.8
2004	14.1		11.3		11.1		10.3	***	14.3		13.5	10.8	***	14.0	11.5
Pooled	**4.1**		**4.2**	***	**4.9**	***	**6.0**	***	**7.4**		**8.0**	**5.1**	***	**7.6**	**5.4**

Table 2.19
Association between credit ratings and firm characteristics associated with default risk (continued)

Rating	AAA		AA		A		BBB		BB		B	Inv grade		Non-inv	All
Def prob	***0.6***		***1.4***		***3.0***		***8.7***		***22.9***		***38.6***	***4.3***		***27.2***	***7.07***
Mean beta estimate															
1987	1.02		1.09		1.04		0.96		1.19		1.47	1.04		1.24	1.06
1988	0.92		0.96	**	1.08		1.08		1.21		1.50	1.03	***	1.31	1.05
1989	0.91		0.99		1.06		1.11	*	1.25	*	1.62	1.04	***	1.36	1.06
1990	0.92		1.01		1.08		1.11		1.24	**	1.58	1.06	***	1.32	1.08
1991	0.92	*	1.03		1.12		1.12	**	1.37		1.71	1.08	***	1.43	1.11
1992	0.93		1.01	**	1.11		1.07	***	1.34		1.49	1.07	***	1.37	1.09
1993	0.92		1.00	***	1.14	*	1.04		1.22		1.37	1.07	*	1.24	1.08
1994	0.93		1.01	**	1.11		1.05		1.20		1.33	1.06		1.21	1.07
1995	0.96		1.01		1.08		1.03		1.11		0.93	1.05		1.10	1.05
1996	0.96		1.01		1.05		0.99		1.08		1.14	1.02		1.09	1.03
1997	0.95		0.99		1.03	*	0.94		1.03		0.94	1.00		1.01	1.00
1998	1.03		1.01		1.03	**	0.94		0.92		0.72	1.00	*	0.86	0.99
1999	0.98		0.98		1.02		0.97	*	1.12		1.21	1.00	**	1.15	1.02
2000	0.95		0.98		1.02	*	0.94	*	1.08		1.02	0.98		1.07	0.99
2001	0.89		0.97		0.93		0.88	**	1.05		1.22	0.92	**	1.10	0.95
2002	0.86		0.98		0.91		0.88	***	1.10		1.23	0.90	***	1.14	0.94
2003	0.85		0.91		0.96		0.90	***	1.26		1.56	0.92	***	1.35	1.01
2004	0.85		0.91		0.95	**	0.85	***	1.20		1.37	0.90	***	1.26	0.98
Pooled	**0.93**	***	**1.00**	**	**1.03**	***	**0.95**	***	**1.15**	**	**1.29**	**0.99**	***	**1.19**	**1.02**
Mean market capitalisation															
1987	26.2	**	6.1	***	3.1		2.5	***	0.8		0.7	5.6	***	0.8	5.3
1988	20.8	**	5.6	***	2.8	*	2.1		1.5	***	0.5	4.8	***	1.1	4.6
1989	22.7	***	6.3	***	3.2	**	2.2	***	1.0		0.5	5.4	***	0.8	5.1
1990	25.7	***	7.0	***	3.7	**	2.2	***	0.9		0.5	5.8	***	0.8	5.5
1991	33.1	***	8.3	***	4.5	***	2.3	*	1.5	*	0.5	6.7	***	1.3	6.3
1992	33.6	***	9.6	**	5.6	***	2.4	*	1.6		1.1	7.6	***	1.5	7.2
1993	33.0	***	10.8	***	5.7	***	3.2	***	1.7		1.2	7.9	***	1.6	7.6
1994	31.6	***	10.3	**	6.1	**	3.9	***	1.8	***	0.6	8.0	***	1.7	7.6
1995	40.9	***	12.5	**	6.9	***	4.0	***	2.0	***	0.7	9.1	***	1.9	8.5
1996	49.6	***	15.1	**	9.3	***	4.9	***	2.6		1.8	11.4	***	2.5	10.7
1997	75.2	***	21.9	**	11.1	***	5.3	**	3.5	***	0.8	14.2	***	2.7	13.1
1998	104.1	**	34.8	***	15.6	***	7.7	***	4.0	***	1.1	19.7	***	3.1	17.9
1999	118.3	**	45.5	**	18.8	***	9.8	***	3.6	*	1.5	24.1	***	2.9	21.7
2000	147.1	**	44.2	*	23.2	***	9.8	*	5.1	**	1.3	25.8	***	4.3	22.8
2001	182.3	**	54.5	***	20.9	***	9.0	**	5.4	**	1.6	25.0	***	4.3	21.8
2002	140.0	**	54.2	***	21.3	***	9.7	***	3.6	**	1.6	23.3	***	3.0	19.7
2003	132.5	**	54.8	***	18.4	***	8.2	***	2.7		1.8	19.8	***	2.4	16.2
2004	148.9	**	63.4	***	22.8	***	10.9	***	4.6	***	2.2	23.9	***	3.8	19.3
Pooled	**71.0**	***	**22.7**	***	**13.0**	***	**7.3**	***	**3.4**	***	**1.5**	**15.7**	***	**2.9**	**14.1**
Mean market-to-book equity ratio															
1987	3.6		2.9		2.5	***	1.8		2.5		3.8	2.6		2.7	2.6
1988	3.3		2.3		2.0	***	1.5	*	2.6		2.9	2.1		2.7	2.2
1989	3.4	*	2.4	*	2.1		1.8		3.0		2.6	2.2		2.9	2.3
1990	3.6	*	2.5		2.8		1.7	*	3.3		2.2	2.6		3.1	2.6
1991	4.4	*	2.7		2.5		2.4		3.0		3.0	2.6		3.0	2.7
1992	4.5	*	3.1		2.6		2.4		8.6		2.5	2.8		7.6	3.2
1993	4.6	**	3.2		2.9		3.0		3.2		4.8	3.1		3.5	3.1
1994	4.0	*	3.1		2.8		2.9		3.1	***	1.3	3.0		3.0	3.0
1995	4.6		3.4		2.9		2.6		7.0		3.7	3.0		6.7	3.3
1996	5.4	*	3.9		3.8		2.9		3.8		3.4	3.7		3.7	3.7
1997	6.7	*	4.7		3.7		3.7		3.6	*	2.0	4.0		3.1	4.0
1998	9.6	*	6.5	*	5.0		4.9		4.5	**	2.3	5.4	**	3.8	5.2
1999	9.3		7.5	*	5.6		5.2		6.5		3.4	5.9		5.5	5.9
2000	8.4		6.9		5.4	***	3.4		4.8	***	2.1	5.0		4.2	4.9
2001	8.2		6.1		5.6	***	3.1		4.4		4.6	4.8		4.4	4.8
2002	6.3		8.8		4.1		5.7		6.3	*	2.3	5.3		5.1	5.3
2003	5.1		7.6		4.0	*	2.7		3.2	**	1.7	3.7	*	2.7	3.5
2004	4.2		6.1		4.3	**	3.1		4.4		3.2	3.9		4.0	3.9
Pooled	**5.4**	***	**4.4**	**	**3.8**		**3.4**	**	**4.6**	***	**2.8**	**3.9**		**4.1**	**3.9**

Now, the issue is whether this information is useful in estimating a reasonable range for the risk premium for small, low market-to-book stocks. The question is then whether the returns differential of 6.9-7.5 percent between decile 1 and 10 stocks exceeds these bounds. Table 2.21 presents the yield spread between 10-year US Treasury Bonds and Lehman Brothers bond indices as at 30 April of each year from 1987-2004 (1990-2004 for the BB- and B-rated indices). The spread for the B-rated index is 4.48 percent, within a 90 percent confidence interval of 3.73 – 5.23 percent. This mean spread is 3.33 percent above the spread for the AAA-rated index and the confidence interval for this spread differential is 2.58 – 4.07 percent, based upon the mean difference in spreads in each year from 1990-2004. So, in the absence of default and interest rate changes, investors in B-rated bonds are likely to earn returns around 2.5-4.0 percent higher than investors in AAA-rated bonds.

Now consider equity investors to be the equivalent of bond investors who rank last in terms of distributions. Also assume that equity investors in small firms bear higher default risk than equity investors in large firms, which is supported by the evidence in Tables 2.19 and 2.20. Can it be the case that the mean excess returns from decile 1 portfolios are due to their greater risk of distress? If this were true, the yield differential relative to AAA-rated bonds is *twice* that being earned by B-rated bondholders. Survivorship bias cannot be completely ruled out. But I have mitigated this risk by comparing actual equity returns with the debt premium which will be earned in the absence of default. Could these additional returns be due to greater market risk? This is unlikely, given that the coefficients on market returns from the regression analysis were significantly negative.

In conclusion, it seems unlikely that the excess returns of around 7 percent from a fundamentals-based investment strategy are due entirely to the greater risk of portfolios formed from these stocks. In Sections 5.1 and 5.2, I accounted for portfolio variance, systematic risk and the size and book-to-market factors. In this section, I address the issue of default risk. I show there is a strong association between credit ratings and size, and a significant but weaker association with the market-to-book ratio. However, the yield differential required by the debt market on B-rated issues relative to AAA-rated issues averaged just 3.3 percent during the sample period. The returns differential of around 7 percent is twice that associated with B-rated bonds over AAA-rated bonds, making it unlikely that these excess returns are due to default risk.

Table 2.20
Ability of firm characteristics to predict credit ratings

Table 2.20 presents statistics which summarise the ability of firm characteristics to predict credit ratings. In each year from 1987 to 2004, 5,557 stocks with credit ratings were ranked according to four firm characteristics: 1) the probability of negative earnings between the end of the explicit forecast period and the end of the competitive advantage period, assumed to be 10 years; 2) the estimated equity beta; 3) market capitalisation; and 4) the market-to-book equity ratio. For each of the four rankings, firms were assigned a synthetic credit rating, based on the distribution of actual credit ratings in that year. For example, in 1996, 5 percent of firms were rated AAA, 18 percent AA and 48 percent A. If a sample firm was ranked at the 30th percentile by the probability of negative earnings, it was assigned a synthetic credit rating of A. The first panel shows the number of correct predictions by credit rating as a percentage of the firms in each ratings class. It also shows the proportion of firms correctly predicted as being either investment grade or non-investment grade, where investment-grade firms have credit ratings of BBB or better. Finally, it shows the proportion of correct predictions. The second panel shows the percentage of correct predictions which are within one ratings class. For example, if a firm was assigned a synthetic rating of BBB and had an actual rating of A, this rating was correct to within one rating class. In each case, the percentage of correct predictions can be compared to the expected percentage correct if synthetic ratings were assigned randomly. This difference is significant at a p-value of at least 2 percent in all cases except for BBB-rated bonds assigned ratings according to equity beta. The significance test conducted was the z-test for the difference between the sample proportion and an estimated population proportion according to the naïve expectations model.

Ranking variable	AAA	AA	A	BBB	BB	B	Inv grade	Non-inv	All
Percentage of correct predictions by credit rating									
Probability of negative earnings	10.1	24.5	46.5	30.0	12.5	12.9	89.5	24.1	33.2
Beta	0.5	19.7	44.1	26.3	20.0	22.0	90.5	31.6	31.0
Market capitalisation	45.0	37.0	53.3	39.9	30.3	47.3	93.7	54.5	44.7
Market-to-book-equity	12.4	25.7	46.8	33.4	12.5	25.3	89.9	27.7	34.9
Naïve expectation	3.9	16.0	42.0	25.9	8.8	3.3	87.9	12.1	28.0
Percentage of predictions correct to within one ratings class either side of the actual rating									
Probability of negative earnings	49.1	76.5	87.1	82.0	61.6	26.9	82.0	52.0	78.3
Beta	28.9	72.9	86.5	74.5	55.8	34.9	77.9	50.1	74.5
Market capitalisation	92.7	86.9	94.7	94.5	77.1	76.3	93.1	76.9	91.1
Market-to-book-equity	55.5	79.6	89.7	85.4	50.5	43.0	85.1	48.4	80.6
Naïve expectation	19.9	61.9	83.9	76.7	38.1	12.1	74.9	30.9	69.6

Table 2.21
Yield spread over US Treasuries by Credit Rating

Table 2.21 presents the yield spread between corporate bonds and 10-year US Treasury bonds for bonds of different credit ratings. The yields are estimates of the yield to maturity, including the reinvestment of coupon payments at the same rate. Yields on corporate bonds refer to Lehman Brothers corporate bond indices. All yields are measured as at the 30th of April each year.

	Spread between Lehman Bros. Index Redemption Yield and 10-year US Treasuries						
Credit rating	**AAA**	**AA**	**A**	**BBB**	**BB**	**B**	**AAA - B**
1987	1.24	1.55	1.78	2.24	---	---	---
1988	0.75	1.20	1.29	1.88	---	---	---
1989	0.74	0.93	1.16	1.64	---	---	---
1990	0.81	0.98	1.26	1.80	2.70	6.71	5.90
1991	0.75	1.06	1.28	1.84	3.36	6.56	5.81
1992	0.65	0.96	1.17	1.53	2.56	4.31	3.66
1993	1.02	1.07	1.43	1.91	3.26	4.77	3.75
1994	0.65	0.80	1.05	1.62	2.43	4.13	3.48
1995	0.81	0.83	1.06	1.61	2.42	3.61	2.80
1996	0.76	0.94	1.12	1.61	2.55	3.49	2.73
1997	0.71	0.94	1.02	1.28	2.07	3.83	3.12
1998	0.73	0.99	1.18	1.42	1.93	3.63	2.90
1999	1.13	1.49	1.65	1.96	2.95	4.36	3.23
2000	2.83	1.80	2.07	2.59	4.63	6.64	3.81
2001	1.62	1.94	2.39	2.85	4.84	2.90	1.28
2002	1.54	1.83	2.11	3.10	4.12	2.74	1.20
2003	1.84	1.39	1.93	2.69	4.84	6.00	4.16
2004	1.46	1.31	1.63	2.19	2.73	3.52	2.06
Mean	**1.15**	**1.22**	**1.49**	**2.00**	**3.16**	**4.48**	**3.33**
Lower 5%	0.87	1.04	1.28	1.74	2.61	3.73	2.58
Upper 5%	1.44	1.40	1.70	2.26	3.71	5.23	4.07

6 Conclusion

The purpose of this study is to determine the merits of a fundamentals-based investment strategy. The modelling assumes that long-term expected returns on firms' investments revert to a normal level over time, and implements this assumption via mean-reversion in revenue growth and profit margins. I also conduct analysis using *Decision-tree* valuations, which incorporate an estimated value of embedded options. Based on the evaluation of portfolio performance, I reach the following conclusions.

First, above-average returns result from an investment strategy which relies on valuations that incorporate rational economic expectations. Under the assumption that revenue growth and profit margins are expected to revert to sustainable levels over time, portfolios formed on the basis of value/price achieve high returns. The difference in mean returns between the top and bottom deciles of stocks ranked on this basis is around 7 percent. However, incorporating the value of embedded options in the analysis did not improve investment performance. While median theoretical values are closer to market price when *Decision-tree* valuations are performed, the ranking of stocks is comparable. 60 percent of stocks are ranked in the same decile, regardless of the assumed competitive advantage period or valuation technique. However, equity analysts may benefit from performing *Decision-tree* valuations if it allows them to estimate target prices in a more sophisticated fashion. I speculate that the overwhelming use of price-earnings ratios to estimate target prices is due to the fact that average *DCF* valuations are consistently below share price. Hence, even if the analyst has superior stock-picking ability they will struggle to justify a target price based on a *DCF* valuation.

The superior investment performance of portfolios formed on the basis of value/price remains once risk is accounted for. Portfolios of stocks with very high or low value/price ratios are typically more volatile than stocks ranking in the middle of this range. I suggest this is due to the relative stability of earnings forecasts compared to share prices. That is, it is more likely that a volatile stock will be identified as relatively over- or under-valued by a theoretical model, when its parameters are estimated using data which is essentially a moving average. Nevertheless, portfolios formed from stocks with high value/price ratios had significantly higher mean Sharpe ratios than portfolios formed from lower-ranked stocks. Hence, outperformance remains after accounting for portfolio volatility.

The stocks selected as relatively undervalued are predominantly small low market-to-book stocks, but the preference towards low market-to-book stocks is reduced once the assumed competitive advantage period is increased. However, there remains evidence of outperformance after controlling for factors associated with stock returns – market risk, size, the book-to-market ratio and momentum. This evidence is in the form of significantly positive intercept terms from linear regressions of returns to long-short investment portfolios on these four explanatory factors.

The valuation models were unable to identify mispriced equities amongst large, high market-to-book stocks. These stocks form the major component of mutual funds and are likely to be the most efficiently priced. Positive risk-adjusted performance is most consistent amongst small, high market-to-book stocks.

Finally, I assessed the magnitude of outperformance against the yield on lower-rated corporate bonds. This assessment was motivated by the association between credit ratings and size. This means that the investment portfolios formed from highly-ranked stocks could have incurred above-average default risk. However, the magnitude of the excess returns earned by long-short portfolios is significantly higher than the default risk premium required by debtholders.

In conclusion, the results support the use of fundamental equity valuation as a portfolio management technique. This conclusion holds provided the analyst uses assumptions regarding long-term revenue growth and profit margin which are consistent with the reinvestment rate and the cost of capital.

Chapter 3

IPO underpricing and the value of embedded options

1. Introduction

In this paper, I explain the underpricing of initial public offers (IPOs) as a function of the proportion of equity value consisting of embedded options, which I label *Real option%*. Investors in firms whose value consists largely of real options face a relatively higher degree of information asymmetry, which is expected to result in lower offer prices and higher returns in the secondary market on the first day of trade. This underpricing is in addition to any returns which result from underwriter or issuer incentives, which I term 'strategic underpricing.'

The results support this prediction. The analysis suggests that, in the absence of any strategic underpricing, the value of embedded options are discounted by 10 percent on average. However, in the absence of strategic underpricing the *Discounted Cash Flow* (*DCF*) component of value is fully priced in the IPO. For an IPO with mean *Real option%* of 47 percent, this result predicts a 5 percent discount to market value. This discount is consistent with information asymmetry explanations for underpricing.

There are two implications of this paper. For investment bankers, it implies that IPO proceeds can be enhanced with efforts to ensure their clients are well-informed about the value of the firm's strategic options. It also provides a technique for estimating this value using simulation analysis, the results of which can be used to ensure investors are fully-informed. Underwriters have an incentive to engage in this activity. The potential increase in proceeds for the mean IPO is $11 million. This equates to increased underwriter fees of $1 million, assuming the typical underwriter fee of 7 percent.

For academics, *Real option%* quantifies information asymmetry in a way which has direct economic meaning. Proxies used in prior literature, such as share allocations to retail investors, the volatility of stock returns, or issue size, provide useful support for information asymmetry arguments. But their relationship with IPO underpricing is not necessarily linear, as assumed in the typical analysis performed. Nor is there any technique which estimates the point at which information asymmetry is reduced. For example, at what point do we consider a client to be a sophisticated investor? What is the threshold issue size at which information asymmetry is no longer material? In contrast, I show there is an approximate linear relationship between IPO underpricing and *Real option%* and quantify this relationship using linear regression.

The paper proceeds as follows. In Section 2 I discuss recent evidence relating to the underpricing of IPOs, motivated by the substantial increase in initial returns observed during 1999-2000, particularly in the technology sector. I also summarise the information asymmetry arguments. In Section 3 I model the linear relationship between IPO underpricing and *Real option%*, provide the economic rationale for its estimation, and summarise the modelling used to measure this variable. The comprehensive modelling of the equity valuation methods which underlie this variable are presented in Chapter 2. Sample data is summarised in Section 4, in which I provide supporting evidence for the interpretation of *Real option%* as a valid economic construct. My intent here is to alleviate any concerns that *Real option%* results from an artificial randomisation process, and therefore lacks economic meaning. I show that the measured relationship between this variable and the volatility of revenue growth will only hold if embedded options are valued by the market. In Sections 5 and 6, I present the results and make concluding comments.

2. IPO underpricing: Recent evidence

Recent evidence on IPO underpricing suggests that IPO underpricing is a strategic decision of underwriters and issuers. For example, there is evidence that underwriters may issue stock at a discount to estimated market value to minimise the risk of holding large quantities of stock in a weak secondary market; or underwriters want to ensure investors are compensated with high initial returns for revealing information about demand for the stock; or, more recently, there is evidence that underwriters reward executives with 'hot stocks' in return for investment banking business (Oxley, 2002). Why issuers allow underpricing to occur is less clear, but there is evidence of greater underpricing when a smaller fraction in the firm is sold in the offer. Therefore, for whatever reason, there is greater underpricing when issuers have less incentives to prevent it. The variables which capture these strategic reasons for underpricing are outlined in Section 3.

However, there is also recent evidence that technology IPOs are consistently underpriced, even after controlling for these factors. Thus, information asymmetry remains a viable explanation for IPO underpricing. In this section, I summarise this recent evidence and the information asymmetry theories of underpricing. It is my contention that the level of information asymmetry for an IPO can be measured as the proportion of firm value comprised of real options, and that this can partially explain IPO underpricing

2.1. The hot issue market of 1999-2000

Ljungqvist and Wilhelm (2003) report that IPO underpricing increased dramatically from 1999-2000, with mean underpricing of 73 and 58 percent in those years for samples of 448 and 366 firms. This compares with mean underpricing of 14-23 percent in the three preceding years. In attempting to explain this underpricing, they find a significant relationship between the level of underpricing and variables they argue act as a proxy for reduced incentives to control underpricing, such as ownership concentration and the level of insider sales. They were able to explain about 45 percent of the variation in first-day returns with these variables and indicator variables for firms classified as (1) high-technology; (2) internet companies, and (3) for IPOs issued during 1999-2000. As further evidence that investment bankers acted on incentives to underprice IPOs, Aggarawl, Purnanandam and Wu (2005) find an association between underpricing and whether the client was required to purchase stock in the secondary market, as part of a tie-in agreement.

An alternative explanation of issuers' willingness to accept the low offer prices proposed by underwriters is what Loughran and Ritter (2004) refer to as the analyst lust hypothesis. This theory contends that firms will leave money on the table in return for research coverage by high-profile analysts employed by prestigious underwriters. They contend that this coverage became more important in the 1990s – when a higher proportion of firm value consisted of growth opportunities, which required analyst research to support investment decisions – and that analyst recommendations became more visible. In support of their theory, they find that IPOs underwritten by top-tier underwriters were overpriced by an average 1.8 percent during the 1980s, and were underpriced by 3.3 percent and 21.2 percent during 1990-1998 and 1999-2000, respectively, after controlling for firm characteristics. In addition, after controlling for underwriter reputation, initial returns for IPOs during 1999-2000 were insignificantly different from zero.

Loughran and Ritter (2004) were only able to explain 20 percent of the variation in returns to IPOs in 1999-2000, compared to 45 percent reported by Ljungqvist and Wilhelm (2003). However, they failed to include the revision of the offer price from the mid-point of the filing range as an explanatory variable, which was significantly positive in the earlier paper. Price revision can be interpreted as an indication of investor demand or a measure of the information revealed by investors about firm value, for which they are compensated by allocations of underpriced IPOs.

While Loughran and Ritter (2004) find evidence consistent with an alternative explanation for increased underpricing in 1999-2000, their results are not inconsistent with those of

Ljungqvist and Wilhelm (2003). For example, they find a significantly positive relationship between initial returns and share overhang, the ratio of retained shares to public float. The authors acknowledge that this is consistent with reduced incentives to control underpricing because the higher the share overhang, the lower the opportunity cost of underpricing. The coefficient on this variable is insignificantly different from zero for 1980-89, but rises to 2.76 for 1990-1998 and 9.35 for 1999-2000, before falling back to 2.23 for 2001-2003. The coefficient of 9.35 for 1999-2000 implies that, if the firm sold just a quarter of its shares in the float (implying that share overhang = 3), expected underpricing would be 28 percent higher than if all shares were sold. But this also implies that the original owners are only leaving 7 percent of equity value on the table. If just 10 percent of shares are sold in the float (implying that share overhang = 9), expected underpricing would be 84 percent higher than if the firm sold all its shares, but the firm has still left just 8 percent of equity value on the table, as the original owners retained 90 percent of the stock.

The evidence of both Ljungqvist and Wilhelm (2003) and Loughran and Ritter (2004) is consistent with management having an incentive to allow underwriters to price IPOs in 1999-2000 at a deeper discount to the expected market price than previously observed. The authors of the first paper contend that management had less incentives to control underpricing due to pre-IPO ownership structure, while Loughran and Ritter argue that issuers were willing to accept lower issue prices if it resulted in increased analyst coverage from prestigious broking houses. Further evidence of additional, systematic underpricing is provided by Houston, James and Karceski (2004). For 65 IPOs from 1996-1998, they report that the average offer price was set at a 5 percent premium compared to a set of comparable firms identified in analyst reports. For 88 IPOs from 1999-2000, this price-setting reverses such that the average offer price was set at a 21 percent discount to the firm's peers. This evidence is consistent with the argument that underwriters systematically priced IPOs at less than the value implied by comparable firm analysis.

Thus, there is evidence from at least four sources that underwriters had additional incentives to underprice IPOs during 1999-2000 and acted in accordance with these incentives. But of relevance for the present study, Ljungqvist and Wilhelm (2003), Loughran and Ritter (2004) and Aggarawl et al (2005), report that, even after controlling for firm characteristics, the *additional* mean underpricing for high-tech and Internet IPOs is significant. Returns to technology investments as a whole were staggering during this period, with the NASDAQ Composite Index rising by an average 70 percent a year in the two years prior to its peak on 10 March 2000.

Hence, despite the fact that the market was pricing listed technology stocks at never-before seen valuation multiples, it only incorporated the same expectations into the price of technology IPOs when they first began trading, and not in the final offer price. This can only be partially explained by ownership characteristics (Ljungqvist and Wilhelm, 2003) and underwriter reputation (Loughran and Ritter, 2004). Specifically, those papers report that firms classified as high-technology companies had, on average, *additional* first-day returns of about 6 percent. Firms classified as internet companies had average additional first-day returns ranging from about 15 percent (Ljungqvist and Wilhelm) to about 35 percent (Loughran and Ritter).

2.2. Information asymmetry and real options valuation

Given the above results, this paper posits that IPO underpricing of technology stocks can be partially explained by the information asymmetry models of Rock (1986) and Beneviste and Spindt (1989), supported by the empirical evidence of Koh and Walter (1989) and Beatty and Ritter (1986).

A potential explanation for this remaining underpricing is the level of information asymmetry between the firm and investors. It is arguable that information asymmetry will be positively associated with the proportion of firm value comprised of embedded options. Hence, we have the hypothesis that the level of underpricing should be positively associated with the proportion of firm value attributable to real options.

2.2.1. Information asymmetry amongst investors

If there is information asymmetry amongst investors, typically partitioned as informed versus uninformed investors, the winners' curse model developed by Rock (1986) implies that the average IPO should be underpriced. This model relies on the assumption that issuers require uninformed investors to participate in the offering in order to raise sufficient investment capital. As uninformed investors are expected to receive a disproportionate share of overpriced IPOs, the only way they will continue to participate in the IPO market is if the average IPO is underpriced, to the point where the expected return to uninformed investors is zero.

This model was formally tested in the Singapore market where detailed information on IPO allocations is available (Koh and Walter, 1989). A sample of 38 IPOs from 1973-1987 showed significant negative correlation between the size of allocation and initial excess returns, consistent with the winners' curse prediction. Further empirical support is found in Beatty and Ritter (1986) who document an inverse relationship between underpricing and issue size, and a direct relationship between underpricing and the number of uses of proceeds. Smaller issues are generally considered to be more speculative; and Beatty and Ritter argue that firms document the uses of proceeds in more detail in response to more stringent SEC regulation of these firms, compared to more established issuers.

Also, a positive association between information asymmetry amongst investors and subsequent returns is consistent with the derivation of the security market line under heterogeneous expectations developed by Williams (1977). In his model, there is a positive association between the dispersion of investors' expectations for future returns and the market's consensus estimate of required returns. This prediction was examined by Doukas, Kim and Pantzalis (2004) who found that the differential performance of value and growth stocks could be partially explained by the dispersion of analyst forecasts. Applying this argument to the IPO case, if information asymmetry amongst investors is reduced once the firm is listed, required returns would be lower and positive initial returns would result.

In this paper, I argue that an increase in the relative proportion of value comprised of real options increases the relative information advantage of sophisticated investors. They will be relatively better informed about the probability of technological success, given the information conveyed directly by management and indirectly by analysts, and will be better placed to value the stock, given this information set. Applying this argument to the informed/uninformed dichotomy, for stocks in which a higher proportion of value is comprised of real options, there will be a larger percentage of uninformed investors. Then, according to the winner's curse model of Rock (1986), it follows that there should be a positive relationship between underpricing and the proportion of value comprised of real options.

The research question addressed in the present paper is analogous to that considered by Ritter (1984), who documented that the mean initial return of 48 percent to IPOs, from January 1980 to March 1981, was largely confined to speculative, natural resources issues. Compare this to the period 1999-2000, when the mean initial return of 66 percent was largely confined to technology firms, and a sharp rise from the 17 percent initial return of the prior three years (Ljungqvist and Wilhelm, 2003). In addition, for the IPOs of 1980-81 the average market-to-book equity ratio based on the offer price increased by just 15 percent, from 2.13 to 2.46, compared to the 45 percent increase in the market-to-book equity ratio of listed firms. We observed the same partial adjustment of offer prices in response to market expectations during the technology bubble, documented by Houston et al, 2004. They report that, in 1999-2000, the average offer price/sales ratio was 21 percent below that predicted by comparable firm analysis, compared to a premium of 5 percent for IPOs from 1996-98.

2.2.2. Information asymmetry between issuers and investors

The same prediction follows from the theory that underpricing is related to the information asymmetry between issuers and investors, as contended by Beneviste and Spindt (1989). In their model, issuers – via their investment bank – canvass market demand in order to set the offer price, typically with reference to an indicative range. While an individual investor is unlikely to have better information about firm prospects, relative to the issuer, the collective information set of investors who participate in the book-build is likely to result in an improved valuation. However, investors are unlikely to reveal the full extent of their information if this results in higher offer prices. Hence, the model predicts that underpricing is related to the degree of information production, typically proxied by offer price relative to the mean of the indicative range.

Empirical support for this explanation is provided from a number of sources Beatty and Ritter (1986) argue that uncertainty amongst issuers and investors is positively associated with the number of intended uses of the capital raised, and inversely related to the size of the issue. They test this prediction by using weighted least squares regression, weighting the variables by ln (1000 + sales). They find a positive association between IPO underpricing and ln (1 + number of uses of proceeds), and the reciprocal of gross proceeds. There is also evidence of a positive association between initial returns and the standard deviation of returns in the after-market (Ritter, 1984; Johnson and Miller, 1988). Finally, Schrand and Verrecchia (2004) find that increased disclosure in the pre-IPO period is associated with lower underpricing.

3. Methodology

This paper attempts to explain returns to technology IPOs as a function of the proportion of firm value consisting of real options. Investors in firms whose value consists largely of real options face a higher degree of information asymmetry, which is expected to result in lower offer prices and higher returns in the secondary market. Using post-listing market and accounting data, I estimate firm values from both real options and discounted cash flow models. I then test whether there is a positive relationship between the proportion of value consisting of real options and returns in the secondary market over various holding periods.

Empirical evidence comparing *DCF* and multiples-based valuations to market values is consistent with the premise that real options comprise some proportion of value. In analysing 51 highly-leveraged transactions from 1983-1989, Kaplan and Ruback (1995) found that *DCF* valuations assuming a constant market-based estimate of systematic risk exceeded transaction values by a mean of just 3.1 percent.

However, sensitivity analysis on the long-term growth rate assumption is consistent with transaction values incorporating a value for real options. The base case valuation estimates were based on the assumptions that the terminal growth rate equals 4 percent, assuming real growth of 0-1 percent and inflation of 3-4 percent, and that depreciation and amortisation is exactly offset by capital expenditure in the terminal state. These assumptions are inconsistent, as there must be some level of reinvestment in order to achieve zero real growth. Simply, maintaining the asset base at a constant nominal amount is consistent with the assumption that cash flows will be maintained at the same level in nominal terms. So inflation is offset by negative real growth.

Under the assumption that the terminal growth rate equals zero, *DCF* values were 11 percent below transaction values on average. This is entirely reasonable, given that *DCF* valuations ignore any price paid for control or the value of real options. It is also consistent with the large-sample evidence of Berger, Ofek and Swary (1996) who report equity market values 11.5 percent higher than the present value of future cash flows for 7,102 firm years from 1985-1990. The latter result is consistent with option values comprising 10 percent of equity value. That is, if the market value of equity exceeds *DCF* value by 11.5 percent, the percentage of market value comprised of *DCF* value is 89.7 percent (1.000/1.115 = 0.897).

Recent evidence on IPO offer prices provides further support for the contention that *DCF* valuations underestimate market values. For example, Cotter, Goyen and Hegarty (2005) estimate three *DCF* values for 71 industrial IPOs in Australia from 1995-98, assuming the firm earns normal returns after 2, 5 and 12 years, respectively. Their median estimate of offer price/intrinsic value ranges from 1.15 to 1.40, compared to 1.03 an intrinsic value estimated using comparable firm price-earnings multiples. This evidence is consistent with option values comprising between 13-29 percent of value. If *DCF* value is \$1.00 and offer price is \$1.40, the proportion of value comprised of *DCF* value is \$1.00/1.40 = 71.4 percent.

In contrast, multiples-based valuation of IPOs provides valuation estimates close to observed offer prices. Kim and Ritter (1999) perform an ordinary least squares (OLS) regression on offer price-earnings ratios against the median price-earnings ratio for comparable firms. For firms more than ten years old, they are able to explain 38 percent of the variation in offer price-earnings, a figure which falls to 15 percent for firms less than ten years old. However, for old firms, they report an intercept term of 6.00 and a coefficient on the comparable price-earnings ratio of 0.45. This implies that, if the median comparable firm has a price-earnings ratio above 10.9, offer prices will be below the value implied by comparable firm analysis. If the median comparable firm has a price-earnings ratio below 10.9, offer prices will be below the value implied by comparable firm analysis. This result is consistent with the evidence of Houston et al (2004) that underwriters priced IPOs at less than the value implied by comparable firm analysis during 1999-2000, a period in which price-earnings ratios were unusually high.

The explanatory power of multiples-based valuation improves when the paper uses enterprise value/sales as its valuation metric, and includes independent variables for profitability and growth (an indicator variable). While profitability is directly related to enterprise value/sales, based on the offer price, the growth variable is only significant for the sub-sample of firms operating for less than 10 years, with a coefficient of 0.23. However, the intercept term in both cases remains significantly positive, which is consistent with offer prices of high growth firms remaining below those implied by comparable firm analysis, even after accounting for growth prospects.

In sum, there is evidence that equity market values exceed *DCF* valuations, regardless of whether market values are based on offer or trading prices, which this paper contends can be considered the value of real options. Further, it contends that the higher proportion of value comprised of real options, the greater will be the information asymmetry, which should be positively related to underpricing. In Sub-section 3.1, I explicitly model the relationship between IPO underpricing, which leads to the hypotheses that there is a positive relationship between underpricing and *Real option%*. In Sub-section 3.2, I summarise the technique used to estimate this variable. The complete derivation of this variable is presented in Chapter 2.

3.1. Operationalised hypotheses and regression models

The theory and evidence cited above is consistent with the IPOs being undervalued by investment bankers due to information asymmetry, which increases with the proportion of equity value comprised of real options. In this section, I model the relationship between the initial return and *Real option%*, which allows estimation of a linear relationship between these variables. This modelling has two important implications. First, the estimated coefficient on *Real option%* has an economic interpretation, which allows me to quantify the relationship between information asymmetry and underpricing. Second, the relationship between initial return and *Real option%* can be estimated after controlling for the variables previously shown to be related to underpricing. This allows me to directly compare my results to previous studies and mitigates against the risk that *Real option%* simply represents a correlated omitted variable.

The market price of an IPO is related to its offer price via the following equation:

$$Market\ price_i = \gamma_i\ IPO\ price_i \quad (3.1)$$

where:

Market price$_i$ = the share price of firm *i* upon listing; and

IPO price$_i$ = the offer price of firm *i* set by the investment bank.

The average coefficient on IPO price (γ) for US IPOs has been about 1.18 (Ritter and Welch, 2002) and potentially represents the IPO discount due to a lack of controls on underwriter incentives to minimise their exposure (Ljungqvist and Wilhelm, 2003), the trade-off between maximising offer proceeds and analyst coverage (Loughran and Ritter, 2004) and information asymmetry (Rock, 1986; Beneviste and Spindt, 1989). The intent of this paper is to quantify the IPO price discount that is attributable to information asymmetry, as measured by the proportion of equity value comprised of real options.

Assume that the investment banker prices the offer at some multiple of theoretical value, θ. In the absence of information asymmetry, and absent any underwriter incentives to underprice the issue – such as increased trade in the secondary market or reduced underwriter risk – this multiple should be equal to one. But in the presence of information asymmetry, or if these other incentives are present, θ will be less than one. In the case of information asymmetry between the investment banker and investors, the model of Beneviste and Spindt (1989) predicts that θ will be less than one to ensure that investors continue to reveal price-relevant information. In the case of information asymmetry amongst investors, the winner's curse model of Rock (1986) predicts that θ will be less than one in order to ensure that uninformed investors earn expected returns of zero. Thus, we have the following equation:

$$IPO\ price_i = \theta_i\ Theoretical\ value_i \quad (3.2)$$

At this stage, the appropriate technique for estimating theoretical value has not been specified. All that has been assumed so far, is that there is some technique for estimating a theoretical value which is equal to the price which equates supply and demand for the stock. Now incorporate the assumption that theoretical value is the sum of the stock's discounted cash flow value and the value of its embedded options. Further assume that the pricing discount applied to each of these two components is not necessarily the same. We can then relate IPO price to the proportion of value comprised of real options via the following equation (3.3):

$$
\begin{aligned}
IPO\ price_i &= \theta_{1,i} DCF\ value + \theta_{2,i} Value\ of\ real\ options_i \\
&= \theta_{1,i}(1 - Real\ option\%_i) \times Theoretical\ value + \theta_{2,i} Real\ option\%_i \times Theoretical\ value_i \\
&= [\theta_{1,i} + (\theta_{2,i} - \theta_{1,i}) Real\ option\%] Theoretical\ value
\end{aligned}
$$

where:

$\theta_{1,i}$ and $\theta_{2,i}$ = the pricing discounts applied to the discounted cash flow valuation and the value of real options due to information asymmetry; and

Real option% = the proportion of equity value that is comprised of embedded options.

We can rearrange the above equation, so that there is an approximately linear relationship between *Real option%* and the percentage difference between theoretical value and IPO price. First, the percentage difference between theoretical value and IPO price can be expressed as:

$$
\frac{Theoretical\ value_i}{IPO\ price_i} - 1 = \frac{1}{\theta_{1,i} + (\theta_{2,i} - \theta_{1,i}) Real\ option\%} - 1 \qquad (3.4)
$$

Second, applying a Taylor series expansion to the first term on the right hand side of the equation, we have (3.5):

$$
\frac{Theoretical\ value_i}{IPO\ price_i} - 1 = \frac{1}{\theta_{1,i}} - \left[\frac{\theta_{2,i} - \theta_{1,i}}{\theta_{1,i}^2}\right] Real\ option\%_i + \left[\frac{(\theta_{2,i} - \theta_{1,i})^2}{\theta_{1,i}^3}\right] Real\ option\%_i^{\ 2}
$$

$$
- \ldots + \left[\frac{(\theta_{2,i} - \theta_{1,i})^n}{\theta_{1,i}^{n+1}}\right] Real\ option\%_i^n - 1
$$

This equation presents an approximately linear relationship between the proportion of equity value comprised of real options and the percentage difference between theoretical value and IPO price. The relationship is approximately linear because the contribution of *Real option%* when an exponent is applied becomes small. Hence, the approximate linear relationship between *Real option%* and the percentage difference between theoretical value and IPO price is as follows:

$$
\frac{Theoretical\ value_i}{IPO\ price_i} - 1 = \left(\frac{1}{\theta_{1,i}} - 1\right) - \left(\frac{\theta_{2,i} - \theta_{1,i}}{\theta_{1,i}^2}\right) Real\ option\%_i \qquad (3.6)
$$

This equation allows me to test the hypothesis that IPO underpricing and information asymmetry are directly related, using the same methodology applied to in prior IPO underpricing studies. The assumption made in IPO underpricing studies related to information asymmetry is that the information asymmetry is resolved upon listed. This could occur because investors are able to observe the true relationship between supply and demand for the stock, as conveyed by share prices. Prior to listing, investors have a limited information set. If we assume that market prices, on average, reflect theoretical value, we have the following equation:

$$\frac{Share\ price_i}{IPO\ price_i} - 1 = \left(\frac{1}{\theta_{1,i}} - 1\right) - \left(\frac{\theta_{2,i} - \theta_{1,i}}{\theta_{1,i}^2}\right) Real\ option\%_i \qquad (3.7)$$

Equation 7 states that the initial return is equal to a constant, plus a multiple of *Real option%*, which is a function of the pricing discount applied to the *DCF* and real options components of equation value. I estimate these coefficients with the following ordinary least squares regression model:

$$\boldsymbol{Initial\ return_i = \alpha + \beta\ Real\ option\%_i + \varepsilon_i}$$

where:

$Initial\ return_i = \dfrac{Closing\ price\ on\ listing\ day}{Offer\ price} - 1$ for stock i;

Real option%$_i$ = the proportion of equity value comprised of real options for stock i; and

ε_i = the error term for stock i

The coefficients estimated in this regression model have a direct economic interpretation, related to the discount factors applied to theoretical value(θ_1 and θ_2). First, the intercept term can be used to estimate the discount factor applied to the *DCF* component of value, via the equation below:

$$\alpha = \frac{1}{\theta_1} - 1 \Rightarrow \theta_1 = \frac{1}{1+\alpha} \qquad (3.8)$$

Second, the coefficient on *Real option%* can be used to estimate the discount factor applied to the value of embedded options. The relationship between θ_1, θ_2 and β can be expressed as follows:

$$\beta = -\left(\frac{\theta_2 - \theta_1}{\theta_1^2}\right) \Rightarrow \theta_2 = \theta_1 - \beta\theta_1^2 \qquad (3.9)$$

Incorporating the estimate for θ_1 into the above equation, we have:

$$\theta_2 = \frac{1}{1+\alpha} - \beta\left(\frac{1}{1+\alpha}\right)^2 \qquad (3.10)$$

This study essentially tests the joint hypotheses that (1) information asymmetry increases with the proportion of theoretical value comprised of real options; and (2) information asymmetry explains some component of IPO underpricing. Consistent with these hypotheses, I expect the coefficient on *Real option%* to be greater than one. I also expect the intercept term to be positive, due to the component of IPO underpricing that is not due to information asymmetry. Further, incorporating the intercept term and the coefficient on *Real option%* into equations 9 and 10 to compute θ_1 and θ_2, I expect the estimate for θ_1 to exceed the estimate for θ_2.

The next stage of analysis is to incorporate control variables previously shown to explain IPO underpricing. Incorporating these controls allows me to isolate the component of IPO underpricing that can be explained by *Real option%*, as opposed to underwriter incentives, hot IPO markets or some other underpricing explanation. The model relied upon in this paper incorporates eight control variables, which can be combined in the following equation. I document the estimation of these parameters in the text which follows.

$$\textbf{Initial return}_i = \alpha + \kappa_1 \textbf{Price revision}_i + \kappa_2 \textbf{Price revision}^{+}_i + \kappa_3 \textbf{Overhang}_i + \kappa_4 \textbf{Size}_i + \kappa_5 \textbf{Pre-issue IPO returns}_i + \kappa_6 \textbf{Pre-issue market returns}_i + \kappa_7 \textbf{Technology}_i + \kappa_8 \textbf{Bubble}_i + \varepsilon_i$$

Price revision during the IPO allocation process is measured as the difference between the final offer price and the mid-point of the indicative offer range; and *Price revision*$^+$ equals *Price revision* where this is positive and zero otherwise. These variables are expected to be positively associated with underpricing, consistent with the results of Bradley and Jordan (2002) and Ljungqvist and Wilhelm (2003).

Overhang is the ratio of common shares retained by the issuer relative to common shares sold in the IPO, as used by Loughran and Ritter (2004) as a measure of the incentives of the issuer to limit the extent of underpricing. That is, the greater the proportion of shares retained by the issuer, the less the issuer has an incentive to control underpricing. An alternative measure of this construct is the ownership concentration of pre-IPO shares held by insiders as measured by the sum of the squared ownership interests of the CEO, venture-capital backers, investment bank and corporate shareholders (Ljungqvist and Wilhelm, 2003). The text of Ljungqvist and Wilhelm (2003) do not mention taking the squared root of the sum of the squared ownership interests, but the data presented in Table III of that paper and the regression coefficients presented in Tables V and VI is consistent with this interpretation. However, the data to estimate this variable was not available.

I use two variables to capture any information content of recent market activity on IPO pricing, due to literature suggestive of there being hot issue markets (Ibbotson and Jaffe, 1975; Ritter, 1984; Bradley and Jordan, 2002; Lowry and Schwert, 2002; and Ritter, 2002). I measure *Pre-issue IPO returns* as the average daily initial return for all IPOs on calendar days -1 to -30 before the issue date and *Pre-issue market returns* as the cumulative return on the NASDAQ index 15 trading days before the issue date.

Technology is an indicator variable for firms listed as "Technology" amongst 11 IBES industry sectors. The technology variable is estimated differently to its counterparts in Ljungqvist and Wilhelm (2003), Loughran and Ritter (2004) and Bradley and Jordan (2002). Those studies found a significant positive relationship between firms classified separately as *high-technology* or *internet-related* firms and IPO underpricing. However, there is no attempt to separately interpret the magnitude of these coefficients on these variables, as the authors acknowledge that there is some arbitrariness to the classification of firms into these two groups and a number of firms will be classified in both groups. For the purposes of this study, I have incorporated only one indicator variable for *Technology* firms which encompasses firms which the previous papers classified as high-technology or internet-related firms. An alternative classification for technology firms is those firms classified under the GICS as Software and Services (4510), Technology Hardware and Equipment (4520), Semiconductors and Semiconductor equipment (4530), Telecommunication Services (5010), Internet Retail (25502020) and Biotechnology (352010). This classification does not materially affect the results.

Bubble is an indicator variable for firms which listed in the years 1999 and 2000. The evidence discussed above in relation to share allocation practices suggests that the significance of the coefficient on this variable diminishes if these controls are in place. I include *size* as a control, as estimated by the natural logarithm of issue proceeds, due to the inverse relationship with initial returns (Bradley and Jordan, 2002) but do not include age (Ljungqvist and Wilhelm, 2003) as a control as this data is unavailable.

I measure the relationship between initial returns and each of the nine individual explanatory variables, and four combinations of variables in a multivariate analysis, which are summarised in Table 3.1. The first and third models are used to assess the explanatory power of the variables which prior research has shown to explain underpricing. The second and fourth models are used to measure the incremental explanatory power of *Real option%* in explaining underpricing. Model 4, which incorporates all nine explanatory variables is as follows:

$$\textit{Initial return}_i = \alpha + \beta \textit{Real option\%} + \kappa_1 \textit{Price revision}_i + \kappa_2 \textit{Price revision}^{+}_i + \kappa_3 \textit{Overhang}_i + \kappa_4 \textit{Size}_i + \kappa_5 \textit{Pre-issue IPO returns}_i + \kappa_6 \textit{Pre-issue market returns}_i + \kappa_7 \textit{Technology}_i + \kappa_8 \textit{Bubble}_i + \varepsilon_i$$

In subsequent analysis, I incorporate additional control variables: the cost of equity capital, initial revenue growth and the initial volatility of revenue growth. I perform this analysis because the magnitude of the association between *Real option%* and initial return, as well as explanatory power, varies within sub-samples partitioned according to these characteristics. I also examine the interaction of *Real option%* and these characteristics. This subsequent analysis is outlined in more detail in Section 5.

Table 3.1
Regression models and expected coefficients

This table summarises the four OLS regression models reported in Table 3.6. Model 1 expresses initial returns as a function of variables previously identified in the IPO literature as being associated with initial returns and takes the form *Initial return* = α + κ_1*Price revision* + κ_2*Price revision*$^+$ + κ_3*Overhang* + κ_4*Size* + κ_5*Pre-issue IPO returns* + κ_6*Pre-issue market returns*. The definitions of these control variables are: *Price revision* = IPO price/Mid-point of the filing range – 1; *Price revision*$^+$ = *Price revision* where *Price revision* is positive, and zero otherwise; *Overhang* = Shares retained by the issuer divided by shares issued; *Size* is the natural logarithm is of issue proceeds; *Pre-issue IPO returns* is the average initial return for IPOs occurring in the 30 calendar days prior to the IPO; and *Pre-issue market returns* is the cumulative return on the S&P1500 Index for the 15 trading days prior to the IPO. Model 3 introduces two additional control variables – *Technology* and *Bubble*. *Technology* is an indicator variable for firms listed as "Technology" amongst 11 IBES industry sectors; and *Bubble* is an indicator variable for IPOs occurring in 1999-2000.

Models 2 and 4 incorporate the explanatory variable of interest, *Real option%*, which is an estimate of the proportion of equity value comprised of the firm's embedded options. It can be computed as 1 – Discounted Cash Flow Valuation/*Decision-tree* valuation. The *Decision-tree* valuation is am estimate of total equity value, and is the mean estimate of 1,000 simulated equity values, in which there is uncertainty over revenue growth and profit margin. These simulated values assume that estimates of revenue growth, profit margin and the volatility of revenue growth revert to long-term expected values over a period referred to as the competitive advantage period, which can take on values from 4-60 year. The competitive advantage period assumed for each firm is that which minimises the percentage difference between the *Decision-tree* valuation and the initial market price. Hence, *Decision-tree* valuations are calibrated to initial market prices. The discounted cash flow valuation is an estimate of equity value which relies on the same competitive advantage period, but which assumes that revenue growth and profit margin revert to long-term expected values in a deterministic fashion. Hence, *Real option%* is an estimate of the proportion of equity value, embedded in market prices, which is not comprised of the *DCF* valuation.

Model	Model 1	Model 2	Model 3	Model 4
Real option%	---	+	---	+
Revision (%)	+	+	+	+
Revision+ (%)	+	+	+	+
Overhang (Shares retained/issued)	+	+	+	+
Size (ln Proceeds)	-	-	-	-
Pre-issue IPO returns (mean last 30 days)	+	+	+	+
Pre-issue market returns (15-day cumulative)	+	+	+	+
Technology (1,0)	---	---	+	+
Bubble (1999-2000=1,0)	---	---	+	+

3.2. Estimating the option component of equity value

In this section, I provide the economic rationale behind the *DCF* and *Decision-tree* valuation models used, summarise the model derivation which is presented in full in Chapter 2, and outline the parameter estimation techniques.

3.2.1. Economic rationale for the model

The primary variable of interest in this paper is an estimate of the proportion of value comprising real options, where total equity value is assumed to comprise the discounted value of expected future dividend payments (the *DCF* valuation) plus the value of real options, presented as equation 11.

Total equity value = *DCF* value + Value of real options (3.11)

In Chapter 2, I derived *Discounted Cash Flow* and *Decision-tree* equity valuation models. These models rely on the assumption that revenue growth and profit margins are expected to revert to long-term expected values over an assumed competitive advantage period. Further, the estimate of long-term revenue growth is the product of the reinvestment rate and the cost of equity capital; and long-term profit margin is equal to the typical margin of established firms. The economic rationale for these assumptions is that abnormal returns on investment are likely to be eroded over time, such that the new investments are expected to earn just their cost of capital, once the competitive advantage period (*CAP*) is over.

The *Decision-tree* valuation model includes the value of the firm's embedded options by incorporating company-specific earnings volatility and a dynamic reinvestment policy. I simulate earnings for each year of the competitive advantage period, by incorporating additional assumptions relating to the volatility of revenue growth and its relationship with profit margin. The *Decision-tree* valuation model incorporates the value of growth options, because states of high growth provide a positive signal to management to increase investment in high-growth markets. This response is incorporated into the model via the assumption of a constant payout ratio, which results in increased investment expenditure in high-growth states, and decreased investment expenditure in low-growth states. In the extreme low-growth state, the firm is bankrupt and exercises its abandonment option.

This dynamic reinvestment policy is the fundamental justification for valuation techniques which include the value of embedded options. The *DCF* valuation ignores the value that can be created via the firm's ability to change its investment policy in response to new information. This results in a lower valuation, because the growth in expected cash flows is independent of the firm's reinvestment policy. If management invests additional capital in projects generating high earnings growth, and reduces investment in low growth projects, the improved capital allocation amongst business units or products will result in realised growth exceeding expectations.

This argument is consistent with the corporate finance literature on the diversification discount, which initial research estimated at about 15 percent (Berger and Ofek, 1995). Research in this area typically involves estimating theoretical value as the sum of the value of individual segments, where segment values are estimated using earnings multiples from comparable single-segment firms. Villalonga (2004) questions whether diversified firms really do trade at a discount to their break-up value. He argues that the firms previously reported as single-segment firms were actually more diversified than first thought, relying on a more detailed database. Once theoretical values are re-computed after taking this increased diversification into account, there is an average value premium for diversification.

However, whether the average diversified firm trades at a discount is not pertinent for my study. What is relevant are the reasons why certain diversified firms trade at a discount. The research consistently finds that a greater discount for firms which overinvest in low-growth segments, relative to high growth segments (Berger and Ofek, 1995; Ahn and Denis, 2004). Improved capital allocation amongst high- and low-growth segments is analogous to increased investment in response to high revenue growth. That is, a dividend payment, as opposed to reinvestment, can be considered an investment in a zero growth segment.

Note that it is not the theory of *Discounted Cash Flow* valuation itself that is the source of the under-estimation of value, but rather the implementation of the model. That is, the expected cash flows incorporated into the *DCF* valuation should, in theory, be the probability-weighted outcome of all possible investments, weighted according to their probability of occurrence. While this can be achieved via Monte Carlo simulation, this does not typically occur in practice.

In sum, *DCF* valuations are typically implemented by assuming a particular portfolio of assets that generate a series of expected cash flows. That is, while a sophisticated analyst may assign probabilities to cash flows being higher or lower than expectations, and appropriately estimate the expected cash flows from an underlying distribution, the probability of making particular investments will be assigned a value of 100 percent or zero. In estimating *Decision-tree* valuations, I consider the investment base to be conditional on growth, so that firms make additional investments in response to the signal that they are in a high-growth state.

3.2.2. Model derivation

I estimate *Real option%* as the proportion of equity value attributable to the firm's embedded options, as opposed to its discounted cash flow valuation. With the *Decision-tree* valuation as an estimate of total equity value, *Real option%* is estimated as follows:

$$Real\ option\% = 1 - \frac{DCF\ valuation}{Decision\text{ - }tree\ valuation} \tag{3.12}$$

In Chapter 2, I derived models for the *DCF* and *Decision-tree* valuations under a set of assumptions consistent with economic theory. In Sub-section 3.2.1, I outlined the economic rationale behind those models and present the models below, along with explanation of their components. For the full model derivation, and a detailed example involving the valuation of

Microsoft, readers should refer to Chapter 2. These models are summarised in Exhibits 1 and 2, below.

The *DCF* model is presented in Exhibit 1. Equity value is a function of revenue growth (g), profit margin (m), the dividend payout ratio (p), the cost of equity capital (r_e) and the length of the competitive advantage period ($n + T$). Revenue growth and profit margin decline asymptotically to long-term expected values, while the cost of equity capital and the dividend payout ratio are held constant. The *Decision-tree* model is presented in exhibit 2. Equity value is the mean estimate of 1000 equity valuations which rely on simulated revenue growth and profit margins.

The *Decision-tree* valuation model involves discounting expected future cash flows at a constant, risk-adjusted discount rate, the cost of equity capital. Hence, it is not technically a *real options* valuation model, which requires the discounting of risk-adjusted cash flows at the risk-free rate. This decision was made in order to reduce the number of parameters required for estimation and to increase its potential usage of the model amongst practitioners who are more comfortable using risk-adjusted discount rates then risk-adjusted cash flows. Specifically, I estimate the cost of equity capital using the standard Capital Asset Pricing Model, which is widely accepted in practice, and which is estimated using standard techniques. Now while there is significant uncertainty over any firm's systematic risk, there is likely to be an equal amount of uncertainty associated with any risk adjustment to simulated cash flows.

Exhibit 3.1
***Discounted Cash Flow* valuation summary**

***DCF* valuation**

The *DCF* valuation is the present value of expected future dividends, where dividends are the product of sales per share (S), profit margin (m) and the dividend payout ratio (p), but cannot be negative. The three terms of the model correspond to the explicit forecast period (n years), the remainder of the competitive advantage period (T years), and the terminal growth period (after year $n + T$).

$$DCF = \sum_{i=1}^{n} \frac{Max(p_i m_i S_i, 0)}{e^{r_e i}} + \sum_{i=n+1}^{n+T-1} \frac{Max\left(p m_i S_n e^{\sum_{i=n+1}^{n+T-1} g_i}, 0 \right)}{e^{r_e i}} + \frac{\overline{m} S_n e^{\sum_{i=n+1}^{n+T} g_i}}{r_e e^{r_e (n+T-1)}}$$

Revenue growth

Revenue growth (g) declines asymptotically to a long-term sustainable rate ($\overline{g}$), estimated as the product of the reinvestment rate ($1 - p$) and the cost of equity capital (r_e).

$$\begin{aligned} g_i &= e^{-\kappa} g_{i-1} + (1 - e^{-\kappa})\overline{g} \\ &= e^{-\kappa(i-n)}(g_n - \overline{g}) + \overline{g} \\ &= e^{-\kappa(i-n)}[g_n - (1-p)r_e] + (1-p)r_e \end{aligned}$$

Profit margin

Profit margin (m) declines asymptotically to a long-term sustainable level ($\overline{m}$), estimated with reference to established firms.

$$\begin{aligned} m_i &= e^{-\kappa} m_{i-1} + (1 - e^{-\kappa})\overline{m} \\ &= e^{-\kappa(i-n)}(m_n - \overline{m}) + \overline{m} \end{aligned}$$

Variable definitions

DCF	= discounted cash flow valuation of equity per share at time 0;
E_i	= earnings per share in year i;
S_i, S_n	= sales per share in years i and n, respectively;
p_i	= dividend payout ratio in year i;
p	= dividend payout ratio from years n + 1 onwards;
g_i	= continuously-compounded sales growth in year i;
g_n	= continuously-compounded sales growth in year n (initial growth);
$\overline{g}$	= long-term sustainable growth rate in sales;
m_i	= net profit margin (earnings/sales) in year i;
m_n	= net profit margin in year n (initial margin);
$\overline{m}$	= long-term sustainable net profit margin;
r_e	= continuously-compounded cost of equity capital; and
κ	= speed of adjustment parameter for sales growth and profit margin.

Exhibit 3.2
***Decision-tree* valuation summary**

***Decision-tree* valuation**

The *DCF* valuation is the present value of expected future dividends, where dividends are the product of sales per share (*S*), profit margin (*m*) and the dividend payout ratio (*p*), but cannot be negative. The three terms of the model correspond to the explicit forecast period (*n* years), the remainder of the competitive advantage period (*T* years), and the terminal growth period (after year $n + T$).

$$DCF^j = \sum_{i=1}^{n} \frac{Max(p_i m_i S_i, 0)}{e^{r_e i}} + \sum_{i=n+1}^{n+T-1} \frac{Max\left(p m_i S_n e^{\sum_{i=n+1}^{n+T-1} g_i}, 0 \right)}{e^{r_e i}} + \frac{\overline{m} S_n e^{\sum_{i=n+1}^{n+T} g_i}}{r_e e^{r_e (n+T-1)}}$$

$$DTV = \sum_{j=1}^{k} \frac{DCF^j}{k}$$

Revenue growth

Revenue growth (g) is the sum of expected growth (μ) and unexpected growth ($\sigma\varepsilon_2$). The standard deviation of unexpected growth declines asymptotically to a long-term estimate $(\overline{\sigma})$.

$$g_i = \mu_i + \sigma_i \varepsilon_2$$

$$\sigma_i = e^{-\kappa}\sigma_{i-1} + \left(1 - e^{-\kappa}\right)\overline{\sigma}$$

Expected revenue growth is also uncertain. Its mean estimate and standard deviation both decline asymptotically to long-term estimates ($\overline{\mu}$ and 0, respectively).

$$\mu_i = e^{-\kappa}\mu_{i-1} + \left(1 - e^{-\kappa}\right)\overline{\mu} + \sqrt{\frac{1 - e^{-2\kappa}}{2\kappa}}\eta_i \varepsilon_1$$

$$\eta_i = e^{-\kappa}\eta_{i-1}$$

Profit margin

Profit margin (m) is a weighted average of the margin on expected sales (m^f) and the margin on unexpected sales ($\hat{m}$), plus a random component. The forecast margin declines asymptotically to its long-term estimate ($\overline{m}$) and the random component is normally distributed with mean zero and standard deviation δ.

$$m_i = m_i^f \left(e^{\mu_i - g_i}\right) + \hat{m}\left(1 - e^{\mu_i - g_i}\right) + \delta\varepsilon_3$$

$$m_i^f = e^{-\kappa} m_{i-1} + \left(1 - e^{-\kappa}\right)\overline{m}$$

$$= e^{-\kappa(i-n)}\left(m_n - \overline{m}\right) + \overline{m}$$

Variable definitions

DCF^j = the discounted cash flow valuation of equity under simulation j of k simulations;
DTV = the *Decision-tree* value of equity;
E_i = estimated earnings in year i;
S_n = estimated sales per share in year n;
p_i, p = dividend payout ratio in year i; and dividend payout ratio from years $n + 1$ onwards;
$\mu_i, \overline{\mu}$ = expected revenue growth in period i and its long-term sustainable level;
$\sqrt{\frac{1 - e^{-2\kappa}}{2\kappa}}\eta_i$ = standard deviation of expected revenue growth in period i;
$\sigma_i, \overline{\sigma}$ = standard deviation of revenue growth in period i and long-term sustainable level;
g_i, g_n, $\overline{g}$ = simulated sales growth in period i; continuously-compounded sales growth in year n (initial growth); and long-term sustainable growth rate in sales;
m_i, m_i^f, $\overline{m}$, $\hat{m}$ = simulated net profit margin in period i; forecast net profit margin in period i, assuming reversion to the long-term margin; long-term net profit margin; and net profit margin on unexpected sales growth;
δ = standard deviation of the random component of profit margin, due to uncertainty over costs;
ε_1, ε_2, ε_3 = standard normal variates.
r_e = continuously-compounded cost of equity capital
κ = speed of adjustment parameter for sales growth and profit margin.

3.2.3. Parameter estimation

The parameter estimation techniques relied upon in this study are the same as those used in the analysis of portfolio performance, presented in Chapter 2. However, there is one significant variation and some minor amendments, which I discuss below.

The significant variation is that I select the competitive advantage period as that which provides the closest match between the *Decision-tree* valuation and the first-day closing price. The theoretical modelling and model fit analysis presented in Chapter 3 showed that the assumed *CAP* has a direct and material impact on *Real option%*. Without information as to market value, estimating the appropriate *CAP* for computing *Real option%* is difficult. If a constant *CAP* is assumed for all firms, *Real option%* will be understated for those firms with a true (unobservable) *CAP* that is longer than assumed. By the same token, *Real option%* will be overstated for firms whose true *CAP* is less than assumed. First, I performed valuations of all IPOs, assuming *CAP* takes on integer values from 4 to 60 years. Second, I selected the *Decision-tree* valuation which minimised absolute percentage error when compared to market price $APE = \left| \frac{DTV - 1st\ day\ close}{1st\ day\ close} \right|$. Using the competitive advantage period which was assumed in this valuation, I estimated the *DCF* valuation and *Real option%*.

Of course, investors in an IPO cannot replicate this analysis because they are unable to observe the market price prior to making their investment. But the purpose of the study is not to determine a trading strategy for IPO investing. The clear evidence of the IPO literature is, to earn abnormal first-day returns from IPO investing, enter into arrangements which ensure large IPO allocations. In other words, even if an equity investor has a vastly superior model to determine which IPOs would be most underpriced, there is no guarantee that they could actually purchase those IPOs.

The purpose of the study is to provide further evidence of underpricing that is unrelated to investment banker choice. IPO underpricing arises from two sources. First, investment bankers make an unbiased assessment of market value, but strategically issue stock at a lower price to this estimate. Explanations for this behaviour include minimising underwriter risk, providing abnormal returns to preferred clients (Oxley, 2002) and publicity generation (Schrand and Verrecchia, 2004 in relation to internet firms). Second, despite their best efforts, underwriters may be unable to persuade investors to purchase stock at this unbiased assessment of value. And it is this second explanation which is likely to be caused by information asymmetry, which I measure as *Real option%*.

Further, there are several examples in the IPO literature in which IPO underpricing is explained by variables which are unobservable prior to listing. For example, uncertainty has been measured using the standard deviation of returns in the after-market (Rock, 1984; Johnson and Miller, 1988; Finn and Higham, 1988). Houston et al (2004) explain offer prices using analyst target prices obtained from research reports up to 115 days after the stock is listed.

This means that a variable very close to the first-day closing price appears on the right-hand side of the equation. But this does not induce a mechanical relationship between initial returns and *Real option%*. This relationship does not exist, because *Real option%* is a function of both the *Decision-tree* valuation and the *DCF* valuation. And the *DCF* valuation has not been calibrated in any way to the first-day closing price, or to the IPO price. In sum, the variable *Real option%* is simply capturing the economic value of uncertainty, in a way that previous measures cannot. That is, while other information asymmetry proxies, such as share allocations amongst retail investors, size, the number of uses of proceeds, or returns volatility, they do not directly measure the economic impact of uncertainty on value. In contrast, *Real option%* is a direct measure of the proportion of equity value attributable to the volatility of expected cash flows. It can be calculated by investment bankers, given their superior information as to the firm's prospects, and they can act on this information. If there is an association between *Real option%* and underpricing, underwriters can devote additional resources to mitigate uncertainty in an attempt to increase the offer price. If there is no association between *Real option%* and underpricing, these efforts are unlikely to lead to higher issue proceeds.

To alleviate any residual concerns that this calibration is inappropriate, I repeated my analysis by incorporating all 57 estimates of *Real option%* in the regression equation. These estimates of *Real option%* are made without any reference to the offer price or the first-day closing price. Because these estimates are highly correlated, the regression coefficients cannot be interpreted in an economic sense. Hence, their coefficients cannot be used to estimate θ_2, which is the proportion of embedded options which are incorporated into the offer price. However, I am able to show that the regression coefficients are jointly different from zero, and there is a further increase in explanatory power. This means that, even estimating *Real option%* using information unrelated to market price, there is an association between IPO underpricing and *Real option%*.

The other relevant information regarding parameter estimation can be summarised as follows:

- I estimated the cost of equity capital (r_e) using the Capital Asset Pricing Model, where the risk-free rate is the annualised yield on 10-year Treasury bonds at the listing date and the market risk premium is 6 percent. Beta is estimated in a three-stage process where stage 1 is computing the coefficient from an ordinary least squares regression of monthly returns of the equity against the S&P1500 Super Index; stage 2 is multiplying this estimate by 2/3 and adding 1/3 (consistent with an adjustment made by Bloomberg); and stage 3 is constraining all beta estimates within the range of 0 to 4. This technique minimises the impact of extreme beta estimates.

- In estimating the parameters which rely on analyst forecasts (initial growth and margins), I used the first available set of forecast information which is available in the IBES database.

- In estimating other valuation parameters, I used the long-term parameter estimates relied upon in the portfolio performance study, presented in Chapter 2. I match firms on the basis of year and IBES industry sector and compute median estimates. For example, in valuing a 1999 Technology IPO, I use the median estimates for Technology stocks in 1999 for long-term growth, long-term margin, the margin on unexpected sales, initial volatility and long-term volatility.

4. Data and valuation metrics

In this section, I conduct a preliminary analysis of the data to establish the external and internal validity of the study, and provide initial evidence that embedded options are likely to be useful in explaining IPO underpricing. In Sub-section 4.1, I present summary data relating to the sample, which shows has comparable characteristics to the population of US IPOs from 1997-2004. I also analyse the relationship between valuation parameters and the resulting valuations, to ensure that valuations are consistent with the theory discussed in Section 3. In Sub-section 4.2, I analyse the relationship between the price-earnings ratios which result from the *Discounted Cash Flow* and *Decision-tree* valuations.

This analysis shows that price-earnings ratios which result from *DCF* valuations exhibit the expected inverse relationship with the cost of equity, and a positive relationship with revenue growth. In contrast, the price-earnings ratios which result from *Decision-tree* valuations – which have been calibrated to market prices – exhibit a positive relationship with the cost of equity and the volatility of initial revenue growth. Apart from an association with the level of growth, there is no theory underlying *DCF* valuations which predicts a positive association between price-earnings ratios and the volatility. Indeed, if volatility of revenue growth is part of risk which is priced by the market, we would observe an inverse relationship between price-earnings ratios and volatility. This provides preliminary evidence that, for the IPO sample, a proportion of equity value is comprised of embedded options. For additional evidence of this supporting argument in relation to the broader class of equities, readers are referred to Chapter 2.

4.1. Sample

For this study to be relied upon in explaining IPO underpricing, the sample must be representative of the population of US IPOs and theoretical valuations must exhibit the expected association with the valuation parameters outlined in Section 3. In this section, I describe the sample, addressing these two issues.

From 1 January 1997 to 31 August 2004, 2454 IPOs were priced in the US, according to NASDAQ. The sample comprises 790 of these issues for which the full set of required data was available. I obtained IPO pricing information from NASDAQ, returns data from Datastream and mean EPS and sales forecasts from IBES (via Datastream). Descriptive statistics on underpricing, market prices, valuation parameters and valuation metrics are presented in Table 3.2 by cohort year, and in Table 3.3 by IBES industry sector.

Comparing the sample with those analysed by Ljunqvist and Wilhelm (2003), and Loughran and Ritter (2004), provides evidence that the sample is representative of the population of IPOs occurring during the eight-year period. Mean initial returns are 33 percent for the sample, which is consistent with the results of the two prior studies. For the sub-sample of 1531 IPOs from 1997-2000, Ljungqvist and Wilhelm report mean initial returns of 43 percent, compared to 44 percent for the 537 IPOs in the present study. For the sub-sample of 1718 IPOs from 1997-2003, Loughran and Ritter report mean initial returns of 39 percent, compared to 37 percent for the 678 IPOs in the present study.

Mean initial returns notably increase to 59 percent during 1999-2000, the years in which there was the highest proportion of technology firms listed (46 percent of IPOs during those years). Again, this is consistent with mean estimates of 66 and 65 percent reported by Ljungqvist and Wilhelm, despite samples sizes twice those of the 349 IPOs in the present study. Technology firms comprise 33 percent of the sample in the present study, compared to 41 percent for the Ljungqvist and Wilhelm sample.

Summary statistics relating to valuation metrics, valuation parameters and explanatory variables for IPO underpricing are also presented in Tables 2 and 3. Valuation metrics are *DCF* and *Decision-tree* valuations (*DCF* and *DTV*), the ratio of these values to offer price

(*DCF/price* and *DTV/price*), the absolute value of the percentage difference between the *Decision-tree* valuation and the first day closing price (*Var)*, the percentage of theoretical value attributed to real options (*Real option%*) and the competitive advantage period (*CAP)*.

Recall that the assumed competitive advantage period for each firm has been selected so as to minimise the absolute difference between the *Decision-tree valuation* and market price. In other words, the assumed competitive advantage period represents the required length of time over which valuation parameters revert to long-term values in order to justify initial share prices. The *DCF* valuation is then performed using the same competitive advantage period, but with the assumption that revenue growth and profit margin, revert to long-term expected values with no uncertainty. The proportion of the *Decision-tree* value which is not attributable to the *DCF* valuation is the estimate of *Real option%.*

The key variable of interest is *Real option%,* which has a mean estimate of 47 percent for the full sample and which is highest for Technology and Healthcare stocks, at 50 and 66 percent, respectively. These sectors are characterised by high, volatile revenue growth, and low initial margins. Consider the median estimates of these parameters, as the mean parameters estimates are affected by skewness, especially for loss-making firms with little sales, whose profit margins can be substantially negative. The typical Healthcare stock was expected to be incurring losses upon listing, as shown by the median initial margin of -72 percent. But with a median initial revenue growth of 38 percent, a firm of this nature could be profitable within a short space of time, provided it survives. The typical Technology stock had comparable initial revenue growth, but was expected to be marginally profitable. Both sectors had high initial volatility of revenue growth: 22 percent for Technology and 33 percent for Healthcare. This combination of high growth, low margins and high volatility results in the high proportion of equity value attributable to embedded options.

These sectors also have the longest median estimates of competitive advantage period, at 32 years for Technology stocks and 28 years for Healthcare stocks. In contrast, firms in the Finance sector had a median *CAP* estimate of 21 years. This difference in *CAP* can be attributed to the relationship between initial and long-term estimates of revenue growth and profit margin. The typical Finance firm had initial revenue growth of 15 percent, which was expected to revert to a long-term estimate of 9 percent (the product of reinvestment rate and the cost of equity capital); and its initial profit margin of 10.8 percent is close to its long-term margin of 10.4 percent. So, under the assumption that revenue growth and margin revert to these long-term values over 21 years, the *Decision-tree* valuation will approximate share price for this finance firm. In contrast, for the median Technology or Healthcare stock, the theoretical value estimate only approximates share price if high revenue growth can be sustained for a longer period. While this also means that the expected profit margins of these firms take longer to reach their long-term estimates, the high revenue growth means that earnings are significantly enhanced via the margin on unexpected sales. For example, the median margin on unexpected sales is 17.7 percent. Now consider a firm in a state where its expected margin is 5.0 percent. If sales are 10 percent above expectations, earnings will be 35.4 percent above expectations $\left(\dfrac{0.05+0.10\times0.177}{0.05}=0.354\right)$. And the longer the competitive advantage period, the more years in which the firm is characterised by high, volatile revenue growth.

Table 3.2
Descriptive statistics by cohort year

Panel A: Underpricing statistics and valuation metrics

Panel A presents descriptive statistics on valuation metrics relating to underpricing, market prices and theoretical valuations. *Return* is the percentage difference between the IPO price and its closing price on the first day's trade. Money left on the table (*MLOTT*) is return multiplied by the number of shares issued, and represents the difference between the market value and cash received for shares sold in the IPO. *IPO price* is the final price listed in the prospectus and *1st close* is the last closing price on the IPO date as reported by Datastream. Variables relating to theoretical valuation are *DCF* (the present value of expected future cash flows), *DTV* (a *Decision-tree* valuation estimated using the simulation technique described in Chapter 2), *Var* (the absolute percentage difference between the *Decision-tree* valuation and the first-day closing price), *Real Option%* (*RO%* - the percentage of theoretical value attributed to real options), and the competitive advantage period (*CAP* - the forecast period which minimises the absolute percentage difference between the first-day closing price and the *Decision-tree* valuation).

		Underpricing				Valuation metrics						
Year	N	Return (%)	MLOTT ($m)	IPO price	1st close	*DCF*	DTV	*DCF /price*	DTV /price	Var (%)	RO%	*CAP*
Means by cohort year												
1997	105	12.7	7	12.30	13.79	12.70	16.60	1.01	1.30	1	39	30
1998	83	18.5	61	13.80	16.81	23.38	20.25	1.52	1.47	0	36	28
1999	165	64.2	107	15.90	29.73	17.50	30.97	1.09	1.85	0	47	32
2000	184	53.9	77	15.19	27.40	11.18	26.11	0.70	1.55	0	56	33
2001	44	13.0	47	15.31	17.51	12.15	19.20	0.77	1.25	0	48	27
2002	47	8.7	15	16.13	17.80	20.30	26.04	1.20	1.55	0	35	21
2003	50	12.9	19	15.20	17.25	10.16	18.77	0.66	1.24	0	51	26
2004	112	10.2	17	14.09	15.74	11.01	18.24	0.66	1.21	0	52	25
All	790	33.1	55	14.72	21.55	14.49	23.27	0.93	1.49	0	47	29
Medians by cohort year												
1997	---	11.1	4	12.00	12.38	7.31	12.84	0.66	1.10	4	35	26
1998	---	12.5	5	13.00	15.69	10.90	16.62	0.74	1.15	3	33	26
1999	---	36.3	28	14.00	20.00	11.28	21.88	0.76	1.42	3	49	32
2000	---	25.0	24	14.63	19.15	7.42	17.58	0.56	1.25	4	57	33
2001	---	11.2	12	14.00	16.30	6.51	16.17	0.53	1.18	4	53	26
2002	---	5.3	8	16.00	16.80	11.90	20.53	0.79	1.12	3	26	16
2003	---	10.0	11	14.25	17.48	6.74	18.22	0.49	1.13	3	55	26
2004	---	5.6	4	13.00	14.01	5.42	14.25	0.40	1.08	2	63	24
All	---	13.6	9	14.00	16.33	8.23	17.06	0.61	1.16	3	49	27
Standard deviation by cohort year												
1997	---	18.4	24	4.56	6.51	19.76	16.70	1.24	0.96	268	32	19
1998	---	24.8	429	4.49	8.14	57.77	16.17	2.78	1.06	83	32	18
1999	---	71.7	248	8.41	27.25	23.04	29.09	1.27	1.24	81	28	16
2000	---	66.6	135	5.70	27.26	11.69	26.28	0.60	0.88	25	28	16
2001	---	17.0	104	6.00	7.82	14.28	12.41	0.84	0.63	60	33	15
2002	---	14.9	44	5.53	7.51	23.83	21.61	1.22	1.01	84	33	14
2003	---	14.3	26	3.42	4.59	9.55	6.70	0.62	0.38	38	32	14
2004	---	14.4	42	8.34	10.21	22.62	20.41	0.68	0.46	42	31	13
All	---	53.1	196	6.54	20.05	26.09	22.90	1.31	0.95	114	31	16

Table 3.2 (contd.)
Descriptive statistics by cohort year

Panel B: First-day returns, money left on the table, valuation parameters and other regression variables

Panel B presents descriptive statistics on valuation parameters and independent variables previously identified in the IPO literature as being associated with initial returns. *Initial volatility* of revenue growth *(Vol)* is estimated as the average standard deviation of revenue growth from firms in the same IBES industry sector using historical financial statement information from 1985 to the year of the IPO; *Long-term volatility* of revenue growth (*Long-term vol*) is estimated in the same way as initial volatility of revenue growth, but uses data drawn from a sample of firms with at least a five-year reporting history; *Initial growth* revenue *(Growth)* is estimated as the mean revenue growth derived from the first three years of available IBES consensus forecasts subsequent to the IPO (fewer forecast years are used if three years of forecasts are not available); *Initial profit margin (Mgn)* is estimated as the mean NPAT/Sales margin obtained from the first three years of available IBES consensus forecasts subsequent to the IPO (fewer forecast years are used if three years of forecasts are not available); *Long-term margin (Long-term mgn)* is estimated as the historical sales-weighted profit margin for firms in the same IBES industry sector using financial statement information from 1985 to the year of the IPO, drawn from a sample of firms with at least a five-year reporting history; *Cost of equity* (r_e) is estimated using the Capital Asset Pricing Model, where the risk-free rate is the annualised yield on 10-year Treasury bonds at the listing date; the market risk premium is assumed to be 6 percent; and beta is estimated in a three-stage process where stage 1 is computing the coefficient from an ordinary least squares regression of monthly returns of the equity against the S&P1500 Super Index, stage 2 is multiplying this estimate by 2/3 and adding 1/3 (consistent with an adjustment made by Bloomberg) and stage 3 is constraining all beta estimates in the range 0 to 4; *Price revision* = IPO price/Mid-point of the filing range – 1; *Tech* is an indicator variable for firms in the IBES industry sector Technology; *Overhang* = Shares retained by the issuer divided by shares issued; *Proceeds* is IPO price multiplied by issued shares; *Pre-issue IPO returns* is the average initial return for IPOs occurring in the 30 calendar days prior to the IPO; and *Pre-issue market returns* is the cumulative return on the S&P1500 Index for the 15 trading days prior to the IPO.

	Valuation parameters (%)								IPO underpricing explanatory variables (%)						
Year	Vol	Long-term vol	Growth	Long-term growth	Mgn	Long-term mgn	Mgn on un-exp sales	r_e	Rev	Rev+	O/Hang	Proceeds ($m)	Pre-issue IPO ret	Pre-issue mkt ret	Tech
Means by cohort year															
1997	18	17	22	13	-39	7.1	9.8	13.7	-9.2	1.2	4.9	61	10	1.7	27
1998	18	18	23	13	-10	7.5	11.4	13.7	-6.8	1.6	5.0	153	19	1.2	27
1999	21	18	45	17	-93	7.6	13.5	16.9	-2.3	3.5	6.4	210	151	0.7	48
2000	25	21	54	17	-272	7.5	16.9	17.5	-4.7	3.4	4.8	129	177	-0.3	45
2001	26	22	24	13	-90	7.1	15.2	13.1	-7.7	1.4	4.3	496	17	0.0	23
2002	29	25	15	11	-11	7.3	14.2	10.9	-9.2	0.7	3.3	310	9	-1.0	19
2003	30	27	19	11	-246	7.6	16.1	11.8	-3.7	1.9	2.6	177	15	0.6	22
2004	32	29	28	13	-68	7.2	32.3	13.8	-12.0	0.9	2.8	170	20	-0.5	20
All	24	21	35	15	-120	7.4	16.5	14.9	-6.4	2.2	4.6	179	81	0.3	33
Medians by cohort year															
1997	14	18	15	13	4.0	7.4	9.8	13.3	-7.1	0.0	3.1	33	11	2.4	---
1998	18	17	20	13	3.6	7.7	8.3	12.9	-5.6	0.0	3.5	46	14	1.2	---
1999	21	17	41	17	-6.2	9.1	8.8	16.8	0.0	0.0	4.4	68	163	0.2	---
2000	22	18	51	17	-46	6.5	11.0	17.1	0.0	0.0	4.0	76	135	-1.1	---
2001	24	21	17	11	3.8	5.9	15.2	11.5	-7.0	0.0	3.5	128	15	-0.8	---
2002	29	26	13	11	3.9	6.2	11.8	10.6	-7.1	0.0	2.9	115	8	-0.7	---
2003	28	26	15	11	5.5	8.1	15.3	11.5	-3.0	0.0	2.5	114	14	0.4	---
2004	30	29	21	13	6.2	5.8	27.7	13.1	-12.5	0.0	2.7	89	20	-0.3	---
All	22	19	25	14	2.7	7.2	14.0	14.1	-5.0	0.0	3.4	72	25	0.1	---
Standard deviations by cohort year															
1997	6	3	28	4	168	1.6	4.8	3.1	13.1	3.0	7.3	98	10	3.2	---
1998	4	4	24	5	77	1.8	9.9	4.4	11.5	4.0	5.3	520	19	3.7	---
1999	3	3	35	6	273	2.0	6.1	5.5	13.4	7.1	7.0	627	65	3.9	---
2000	6	6	34	5	657	1.6	10.0	5.2	14.8	6.1	4.6	235	151	4.1	---
2001	7	5	35	5	407	2.1	6.5	4.9	11.5	3.8	4.0	1357	9	4.2	---
2002	7	6	23	3	73	2.2	11.6	2.9	11.3	2.2	2.6	734	6	5.0	---
2003	8	6	17	6	948	2.3	13.3	4.9	9.5	4.4	1.7	167	8	2.3	---
2004	9	6	25	7	337	2.3	16.8	6.3	13.4	3.1	2.0	272	9	2.3	---
All	8	6	33	6	459	1.9	12.3	5.4	13.4	5.2	5.3	526	109	3.7	---

Table 3.3
Descriptive statistics by IBES industry sector

Panel A: First-day returns, money left on the table and valuation metrics

Panel A presents descriptive statistics on valuation metrics relating to underpricing, market prices and theoretical valuations. *Return* is the percentage difference between the IPO price and its closing price on the first day's trade. Money left on the table (*MLOTT*) is return multiplied by the number of shares issued, and represents the difference between the market value and cash received for shares sold in the IPO. *IPO price* is the final price listed in the prospectus and *1st close* is the last closing price on the IPO date as reported by Datastream. Variables relating to theoretical valuation are *DCF* (the present value of expected future cash flows), *DTV* (a *Decision-tree* valuation estimated using the simulation technique described in Chapter 2), *Var* (the absolute percentage difference between the *Decision-tree* valuation and the first-day closing price), *Real Option%* (*RO%* - the percentage of theoretical value attributed to real options), and the competitive advantage period (*CAP* - the forecast period which minimises the absolute percentage difference between the first-day closing price and the *Decision-tree* valuation).

IBES industry sectors are Basic Industries *(BAS)*, Capital Goods *(CAP)*, Consumer Durables *(CD)*, Consumer Non-durables *(CND)*, Consumer Services *(CSV)*, Energy *(ENE)*, Finance *(FIN)*, Healthcare *(HTH)*, Technology *(TCH)*, Transport *(TRA)* and Utilities *(UTI)*.

		Underpricing				Valuation metrics						
Year	N	Return (%)	MLOTT ($m)	IPO price	1st close	*DCF*	DTV	*DCF* /price	DTV /price	Var (%)	RO%	*CAP*
Means by IBES industry sector												
BAS	13	7.0	-3	16.22	15.55	18.91	24.34	1.18	1.53	1	31	25
CAP	28	15.7	24	15.03	17.81	17.56	22.14	1.22	1.49	0	31	23
CD	16	10.1	15	13.92	15.30	17.13	20.61	1.09	1.36	0	28	25
CND	25	14.4	18	15.36	17.55	17.48	21.91	1.14	1.42	0	29	26
CSV	155	29.5	35	14.49	19.69	16.03	23.46	1.14	1.59	0	44	28
ENE	28	14.6	154	16.06	18.92	15.09	22.48	0.87	1.32	0	41	24
FIN	87	10.8	32	15.62	17.45	16.05	21.36	1.02	1.33	0	35	26
HTH	149	21.0	26	13.35	17.05	6.79	16.80	0.52	1.24	0	66	29
TCH	264	59.1	86	14.70	28.18	15.90	27.74	0.96	1.67	0	50	33
TRA	15	11.7	147	18.82	22.06	23.03	28.14	0.95	1.24	0	27	27
UTI	10	26.8	62	18.15	22.83	14.19	20.01	0.77	1.10	0	36	27
All	790	33.1	55	14.72	21.55	14.49	23.27	0.93	1.49	0	47	29
Medians by IBES industry sector												
BAS	---	1.0	1	15.00	15.03	12.40	21.30	0.75	1.11	4	26	25
CAP	---	7.1	4	14.50	16.35	14.63	19.12	0.74	1.16	2	32	22
CD	---	3.9	2	13.00	16.16	10.00	17.00	0.82	1.19	4	14	21
CND	---	15.9	12	14.00	16.50	12.10	19.48	0.84	1.20	4	13	24
CSV	---	13.3	12	14.00	17.31	9.05	18.66	0.66	1.22	3	44	26
ENE	---	9.8	6	15.00	16.14	9.27	16.09	0.62	1.12	5	45	23
FIN	---	7.3	3	14.00	15.88	9.51	16.53	0.70	1.10	4	27	21
HTH	---	9.1	5	13.00	14.03	3.89	14.04	0.30	1.08	4	75	28
TCH	---	30.7	23	14.00	18.23	8.71	17.60	0.67	1.33	3	50	32
TRA	---	7.2	11	17.00	17.44	10.51	17.51	0.79	1.08	1	29	26
UTI	---	16.2	39	16.75	21.64	11.82	20.41	0.93	1.10	5	23	22
All	---	13.6	9	14.00	16.33	8.23	17.06	0.61	1.16	3	49	27
Standard deviation by IBES industry sector												
BAS	---	19.8	62	6.43	6.49	20.51	18.50	1.28	1.14	128	28	17
CAP	---	38.1	59	4.92	9.08	17.93	16.98	1.15	0.87	74	28	17
CD	---	16.9	41	5.28	5.68	17.17	15.27	0.75	0.52	52	31	18
CND	---	14.4	47	6.36	7.09	16.73	14.31	1.04	0.80	52	31	18
CSV	---	49.3	75	4.34	12.31	23.77	18.94	1.60	1.13	134	31	17
ENE	---	20.4	737	5.04	8.69	20.87	19.90	0.91	0.74	59	32	16
FIN	---	21.4	136	5.89	8.07	18.30	17.59	1.06	0.92	82	31	18
HTH	---	41.1	85	7.62	14.60	12.65	13.31	0.92	0.64	198	28	14
TCH	---	67.2	167	7.18	29.42	35.31	30.40	1.48	1.04	39	27	16
TRA	---	19.1	509	9.70	15.27	37.57	36.12	0.70	0.58	34	24	18
UTI	---	25.6	68	5.74	7.53	11.55	9.88	0.46	0.43	25	33	20
All	---	53.1	196	6.54	20.05	26.09	22.90	1.31	0.95	114	31	16

Table 3.3 (contd.)
Descriptive statistics by IBES industry sector

Panel B: First-day returns, money left on the table, valuation parameters and other regression variables

Panel B presents descriptive statistics on valuation parameters and independent variables previously identified in the IPO literature as being associated with initial returns. *Initial volatility* of revenue growth *(Vol)* is estimated as the average standard deviation of revenue growth from firms in the same IBES industry sector using historical financial statement information from 1985 to the year of the IPO; *Long-term volatility* of revenue growth (*Long-term vol*) is estimated in the same way as initial volatility of revenue growth, but uses data drawn from a sample of firms with at least a five-year reporting history; *Initial growth* revenue *(Growth)* is estimated as the mean revenue growth derived from the first three years of available IBES consensus forecasts subsequent to the IPO (fewer forecast years are used if three years of forecasts are not available); *Initial profit margin (Mgn)* is estimated as the mean NPAT/Sales margin obtained from the first three years of available IBES consensus forecasts subsequent to the IPO (fewer forecast years are used if three years of forecasts are not available); *Long-term margin (Long-term mgn)* is estimated as the historical sales-weighted profit margin for firms in the same IBES industry sector using financial statement information from 1985 to the year of the IPO, drawn from a sample of firms with at least a five-year reporting history; *Cost of equity* (r_e) is estimated using the Capital Asset Pricing Model, where the risk-free rate is the annualised yield on 10-year Treasury bonds at the listing date; the market risk premium is assumed to be 6 percent; and beta is estimated in a three-stage process where stage 1 is computing the coefficient from an ordinary least squares regression of monthly returns of the equity against the S&P1500 Super Index, stage 2 is multiplying this estimate by 2/3 and adding 1/3 (consistent with an adjustment made by Bloomberg) and stage 3 is constraining all beta estimates in the range 0 to 4; *Price revision* = IPO price/Mid-point of the filing range – 1; *Bubble* is an indicator variable for IPOs from 1999-2000; *Overhang* = Shares retained by the issuer divided by shares issued; *Proceeds* is IPO price multiplied by issued shares; *Pre-issue IPO returns* is the average initial return for IPOs occurring in the 30 calendar days prior to the IPO; and *Pre-issue market returns* is the cumulative return on the S&P1500 Index for the 15 trading days prior to the IPO.

Year	Valuation parameters (%)								IPO underpricing explanatory variables (%)						
	Vol	Long-term vol	Growth	Long-term growth	Mgn	Long-term mgn	Mgn on un-exp sales	r_e	Rev	Rev+	O/Hang	Proceeds ($m)	Pre-issue IPO ret	Pre-issue mkt ret	Bubble
Means by cohort year															
BAS	21	16	24	12	-51	5.7	13.1	13.1	-9.0	1.4	2.7	318	61	0.7	38
CAP	20	19	23	11	2.5	5.1	7.4	11.9	-9.1	1.0	3.2	144	45	-0.5	21
CD	16	15	13	12	6.2	5.1	21.1	12.2	-9.6	0.0	3.4	206	40	1.7	19
CND	16	13	15	11	-190	6.2	18.3	11.7	-7.9	1.5	3.6	580	33	0.7	28
CSV	21	21	33	14	-114	5.3	11.2	14.5	-5.1	2.6	4.4	140	89	0.2	45
ENE	29	27	27	10	-16	5.8	11.4	11.3	-6.5	1.5	3.2	271	40	0.8	32
FIN	22	20	16	10	5.9	10.4	26.0	11.3	-7.7	0.6	3.0	337	31	0.2	17
HTH	36	29	44	14	-384	6.3	13.9	13.8	-11.3	1.1	4.2	97	70	0.2	44
TCH	22	19	44	18	-49	9.0	19.5	18.3	-3.5	3.7	6.1	118	119	0.3	61
TRA	14	14	13	12	11	6.2	20.6	13.1	-6.2	1.5	3.3	545	36	1.4	13
UTI	17	15	34	17	-163	10.6	5.6	19.0	-0.9	1.8	5.2	335	82	1.0	50
All	24	21	35	15	-120	7.4	16.5	14.9	-6.4	2.2	4.6	179	81	0.3	44
Medians by cohort year															
BAS	20	17	7	11	2.9	5.6	8.3	12.2	-11.1	0.0	1.3	171	15	-0.2	---
CAP	20	18	17	10	4.6	5.3	7.3	11.2	-8.0	0.0	2.6	85	22	-1.0	---
CD	13	12	10	11	6.0	5.1	16.4	11.1	-6.1	0.0	3.3	72	14	1.2	---
CND	14	12	12	11	2.7	6.5	16.6	11.5	-3.6	0.0	2.6	77	19	0.0	---
CSV	21	21	22	13	1.6	5.2	8.8	13.1	0.0	0.0	3.2	77	26	-0.2	---
ENE	28	26	18	10	6.0	5.6	12.5	10.6	-5.0	0.0	2.6	87	17	-0.3	---
FIN	26	21	15	9	10.8	10.4	15.8	10.6	-7.1	0.0	2.4	115	18	0.1	---
HTH	33	29	38	14	-72	6.5	11.0	13.5	-10.0	0.0	3.4	59	26	0.3	---
TCH	22	18	36	18	2.6	9.0	17.7	18.4	0.0	0.0	4.3	62	73	0.0	---
TRA	15	15	5	12	5.3	6.2	11.8	13.2	-5.3	0.0	2.3	147	23	1.4	---
UTI	16	14	30	20	-10	10.6	6.3	20.3	0.0	0.0	5.4	143	41	-1.3	---
All	22	19	25	14	2.7	7.2	14.0	14.1	-5.0	0.0	3.4	72	25	0.1	---
Standard deviations by cohort year															
BAS	2	3	38	5	182	0.1	16.8	4.2	10.1	4.9	2.5	388	76	4.3	---
CAP	3	2	28	4	19	0.2	2.9	3.4	10.7	2.9	2.6	243	55	3.8	---
CD	5	4	13	5	5	0.1	12.7	4.4	9.3	0.0	1.7	429	67	3.6	---
CND	2	3	24	3	949	0.6	15.2	2.3	13.1	2.9	4.2	1756	44	3.8	---
CSV	5	3	32	5	432	0.4	7.9	5.2	14.0	6.6	5.1	286	120	3.7	---
ENE	5	5	26	5	83	1.1	6.3	3.1	10.6	3.8	2.1	818	57	4.2	---
FIN	5	4	28	5	41	0.1	15.8	3.5	8.5	2.1	2.8	724	43	3.4	---
HTH	6	6	32	5	796	0.8	7.1	4.6	14.4	3.2	4.9	233	86	3.6	---
TCH	5	5	32	5	156	0.2	12.7	5.3	14.2	6.1	6.8	241	131	3.8	---
TRA	1	1	18	5	17	0.4	18.7	3.8	11.8	4.9	4.1	1370	58	3.5	---
UTI	4	5	54	9	290	0.1	1.8	6.3	10.0	4.3	2.7	459	107	4.8	---
All	8	6	33	6	459	1.9	12.3	5.4	13.4	5.2	5.3	526	109	3.7	---

4.2. Valuation, risk and growth

In this section, I provide preliminary evidence that market prices exceed *DCF* valuations. That evidence motivates the hypothesis that *Real option%* is associated with underpricing, on the basis that there is less information asymmetry associated with the *DCF* component of value, compared to the real option component. The preliminary evidence involves comparing *DCF* value/price ratios with those of prior research, and examining of theoretical price-earnings ratios. I analyse the relationship between the price the relationship between price-earnings ratios implied by the *Decision-tree* valuations and three value drivers: the cost of equity capital, initial revenue growth and the initial volatility of revenue growth.

4.2.1. DCF valuations, Real option%, risk and growth

Real option% is determined by the difference between the *Decision-tree* and *DCF* valuations, under the same competitive advantage period. The assumed *CAP* for each issue is that which minimises the difference between the *Decision-tree* valuation and the first-day closing price. Referring to Tables 2 and 3, we see that the median ratio of *DCF* value to IPO price is 0.61, while the median ratio of *Decision-tree* value to price is 1.16. This leads to an issue of internal validity. What if the calibration of *Decision-tree* values to market prices was spurious, and *DCF values* are a more appropriate estimate of theoretical value? The evidence of Bradshaw (2004) provides support for the case that market values typically exceed *DCF* valuations. Further, initial revenue growth and the volatility of this growth explain a large proportion of the variation in *Real option%.* I present this evidence to allay any concerns that this parameter estimate is simply an artificial result of calibrating the *Decision-tree* value to market price. In other words, the data supports my contention that *Real option%* is likely to proxy for information asymmetry, and therefore is expected to be positively associated with IPO underpricing.

Based on 46,209 valuations from 1994-1998, Bradshaw (2004) estimated a median value/price ratio of 0.59 using a residual income valuation model. He assumes that residual income declines to a long-term estimate of zero. This assumption relies on the same economic theory which justifies my assumption that revenue growth and margins approach long-term estimates consistent with abnormal investment returns being eroded over time. Further, Bradshaw's mean assumption about the rate at which residual income declines is comparable to my median *CAP* assumption of 27 years. Even assuming residual income can continue into perpetuity after forecast year 5, his median value/price ratio is just 0.77.

The median *Real option%* is 49 percent and is highest for the Healthcare and Technology sectors, at 75 and 50 percent, respectively. In Table 3.4, I present data which shows the association between *Real option%* and the key determinants of this estimate – volatility, growth and the cost of equity. First, I partitioned the sample into nine groups, based on the 33rd and 67th percentiles according to a sort on the cost of equity and initial revenue growth. In Panel A, I show the correlation between the volatility of revenue growth and *Real option%* for the full sample and the nine sub-samples. For the full sample, this correlation is 0.29, and increases with the initial growth estimate. Therefore, firms with high, volatile revenue growth have high *Real option%*.

In panel B, I present the mean *Real option%* for 27 sub-samples formed from the 33rd and 67th percentiles of initial volatility, initial revenue growth and the cost of equity. Consistent with the correlations shown in Panel A, *Real option%* increases with an increase in volatility, rising from 38 percent for the low volatility sample, to 57 percent for the high volatility sample. This relationship is most apparent for high-growth firms. For this sub-sample, the mean *Real option%* increases from 32 percent for low-volatility firms to 63 percent for high-volatility firms.

This information supports my contention that *Real option%* proxies for information asymmetry. Recall that the *CAP* assumption is selected so as to minimise the difference between the *Decision-tree* value and the first-day closing price. My contention is that, when a *DCF* valuation is estimated under the same *CAP*, the difference between the two valuations is the value of embedded options. Now consider an alternative hypothesis. Say that embedded options were valued at zero by the market, and that the estimate of *Real option%* was simply an artifact of a simulation model involving the randomisation of parameters unrelated to value. In this instance, the estimated *Real option%* would be associated with *Real option%* in a way contrary to expectations.

Consider two comparable IPOs whose only difference is the volatility of revenue growth. If, in reality, market price is unrelated to volatility, they will have the same market price. Now, when I compute *Decision-tree* values, the high volatility stock will have the lower *CAP*. This occurs because the *Decision-tree* value will reach market price using less forecast years. What this means is that I will estimate *Real option%* for the lower volatility stock using a long *CAP*, and I will estimate *Real option%* for the higher volatility stock using a shorter *CAP*. Further, we know from the analysis presented in Chapter 2 that there is a positive relationship between the assumed *CAP* and *Real option%*. So, for two IPOs which are comparable except for volatility:

If market prices are unrelated to volatility, the estimated Real option% for the low volatility stock will be greater, than the estimated Real option% for the high volatility stock. This occurs because the lower volatility stock will have a longer estimated CAP.

This is not what we observe in Table 3.4. We observe a positive association between *Real option%* and volatility. In conclusion, the valuations summarised in Tables 2-4 support the interpretation of *Real option%* as the proportion of value attributed to embedded options. The data shows that:

- *DCF* valuations are materially below market prices, but are comparable to a large-sample study which relied on similar economic assumptions;
- *Real option%* is positively associated with the volatility of revenue growth, which would not be expected to occur if volatility was not factored into market prices.

Table 3.4
Relationship between initial volatility and the proportion of equity value attributable to real options

In Table 3.4, I summarise the relationship between the initial volatility of revenue growth and the proportion of equity value attributable to real options (*Real option%).* This the percentage difference between a *Decision-tree* and *DCF* valuation of equity, whose models are summarised in Exhibits 1 and 2. The sample comprises 790 US IPOs which were issued from 1997-2004. Panel A shows the Pearson correlation coefficients which measure the association between initial volatility of revenue growth and *Real option%.* This data is presented for the full sample, for sub-samples based on the 33rd and 67th percentiles of initial growth and the cost of equity, and for nine sub-samples based on the intersection of those cut-offs. Panel B shows the mean *Real option%* for the full sample and for sub-samples based on he 33rd and 67th percentile of initial revenue growth, initial volatility of revenue growth and the cost of equity capital.

Initial volatility of revenue growth *(Vol)* is estimated as the average standard deviation of revenue growth from firms in the same IBES industry sector using historical financial statement information from 1985 to the year of the IPO; *Initial growth* revenue *(Growth)* is estimated as the mean revenue growth derived from the first three years of available IBES consensus forecasts subsequent to the IPO (fewer forecast years are used if three years of forecasts are not available); *Cost of equity* (r_e) is estimated using the Capital Asset Pricing Model, where the risk-free rate is the annualised yield on 10-year Treasury bonds at the listing date; the market risk premium is 6 percent; and beta is estimated in a three-stage process where stage 1 is computing the coefficient from an ordinary least squares regression of monthly returns of the equity against the S&P1500 Super Index, stage 2 is multiplying this estimate by 2/3 and adding 1/3 (consistent with an adjustment made by Bloomberg) and stage 3 is constraining all beta estimates in the range 0 to 4.

Panel A: Correlation between initial volatility of revenue growth and the proportion of value attributable to real options

		Initial Growth			
		Low	Med	High	All growth
Cost of equity	Low	0.19 (0.04)	0.52 (<0.01)	0.46 (<0.01)	0.35 (<0.01)
	Med	0.11 (0.31)	0.51 (<0.01)	0.62 (<0.01)	0.34 (<0.01)
	High	0.22 (0.15)	0.46 (<0.01)	0.56 (<0.01)	0.38 (<0.01)
	All cost of equity	0.10 (<0.01)	0.41 (<0.01)	0.51 (<0.01)	0.29 (<0.01)

Panel B: Mean Real option%

Cost of equity partition	Initial growth partition	Initial volatility partition				
		Low volatility	Medium volatility	High volatility	All volatility	All growth and volatility
Low cost of equity	Low growth	27	40	39	34	
	Med growth	19	29	41	32	33
	High growth	23	13	51	33	
Medium cost of equity	Low growth	58	52	66	50	
	Med growth	35	50	65	59	51
	High growth	28	36	61	44	
High cost of equity	Low growth	73	80	85	79	
	Med growth	43	68	76	63	57
	High growth	38	44	72	48	
All cost of equity	Low growth	45	58	52	50	
	Med growth	32	51	57	47	
	High growth	32	41	63	44	
All cost of equity and growth		38	48	57	47	

4.2.2. Relationship between price-earnings ratios, risk and growth

In the previous section, I provided supporting evidence for my interpretation of *Real option%* as the estimated proportion of equity value attributable to embedded options. As further support, I analyse the relationship between price-earnings ratios, systematic risk, revenue growth and the volatility of that growth. As a whole, there is a positive association between price-earnings ratios, systematic risk and the volatility of revenue growth. This association is contrary to expectations from *DCF* valuations.

All else being equal, *Discounted Cash Flow* valuations imply that the price-earnings ratio has an inverse relationship with the cost of equity capital, a positive relationship with earnings growth, and no relationship with the volatility of revenue or earnings growth. Of course, these variables can interact so that this relationship does not hold. For instance, if reinvested earnings are expected to earn the cost of equity capital, there is no relationship between the price-earnings ratio and growth; and if volatility is correlated with the cost of equity capital, there will be an inverse relationship between volatility and the price-earnings ratio. In contrast, a real options valuation implies a positive relationship between the price-earnings ratio and the volatility of earnings growth. This occurs because the volatility of earnings gives rise to growth and abandonment options, which increase equity value if exercised in an optimal way.

I examine whether these expected relationships are evident in the data, when theoretical price-earnings ratios are computed. I consider a sub-sample of 454 firms whose theoretical price-earnings ratios for year three are between 0 and 100, and illustrate the relationship between these ratios and three value drivers: the cost of equity capital, initial revenue growth and the initial volatility of revenue growth.

Figure 1 presents the graphs of mean price-earnings ratios for firms grouped according to the cost of equity capital, initial revenue growth and the initial volatility of revenue growth. On average, *DCF* valuations result in the expected inverse relationship between price-earnings ratios and the cost of equity, a direct relationship with initial revenue growth, and no relationship with the volatility of revenue growth. In contrast, *Decision-tree* valuations result in a direct relationship between price-earnings ratios the cost of equity capital and volatility.

Of course, the *Decision-tree* valuations have been calibrated to approximate market prices. So Figure 1 illustrates that *actual* price-earnings ratios from 1997-2004 were highest for IPOs stocks with high cost of equity and high volatility of revenue growth, the direct opposite of what we would expect if market prices reflected simply discounted cash flow valuations.

Thus, the gap between the lines in each panel can be interpreted as the price-earnings premium of market prices over discounted cash flow valuation.

This positive relationship between the price-earnings ratio, the cost of equity and revenue volatility, is even more apparent after controlling for interactions amongst these value drivers. I partition the full sample of 790 firms into 27 sub-samples based on the 33rd the 67th percentiles of the cost of equity, initial revenue growth and the volatility of initial revenue growth. This allows me to present the relationship between price-earnings ratios and one value driver, for sub-samples whose values for the other two value drivers are roughly comparable. These relationships are illustrated in Figure 2, for 12 sub-samples.

The four panels of Panel A present the mean price-earnings ratio for groups with low, medium and high cost of equity capital, for groups whose initial revenue growth and volatility are comparable. For example, the panel in the top left is for the sub-sample of firms with medium initial revenue growth and volatility. The other panels relate to high-growth, high-volatility firms; low-growth, low-volatility firms; and high-growth, high-volatility firms. In general, *DCF* valuations result in an inverse relationship between the mean price-earnings ratio and the cost of equity capital. This relationship is most apparent for low volatility firms, whose *DCF* valuations are closest to *Decision-tree* valuations and, of course, market prices.

Compare this result to the price-earnings ratios which result from *Decision-tree* valuations. These valuations typically exhibit a positive relationship with the cost of equity capital, and only trend downwards for high-growth, low volatility firms. Hence, despite selecting firms with comparable revenue growth and volatility, there remains a positive relationship between price-earnings ratios and the cost of equity capital.

There is also a positive relationship between the initial volatility of revenue growth, and the price-earnings ratios, as shown in Panel C. Under *DCF* valuations, this relationship only holds if volatility of revenue growth is positively associated with the magnitude of growth, or inversely related to the cost of equity capital. For sub-samples in which these factors are comparable, price-earnings ratios which result from *DCF* valuations should be comparable. Hence, the positive association between price-earnings ratios and volatility is consistent with market prices taking account of some source of value in addition to the *DCF* valuation. Note that the price-earnings ratios derived from *DCF* valuations also exhibit the same, positive relationship with volatility. But this only occurs because they are derived under the same competitive advantage period which underlies the *Decision-tree* valuations, and the competitive advantage period increases for firms with high price-earnings ratios.

Figure 3.1
Price-earnings ratios relative to the cost of equity capital, initial revenue growth and the initial volatility of revenue growth

Figure 1 illustrates the relationship between the mean ratio of theoretical price to year 3 forecast earnings per share and three variables – the cost of equity capital, initial revenue growth and the initial volatility of revenue growth. The data is drawn from a sub-sample of 454 firms with positive earnings forecasts, and whose theoretical price-earnings ratios are less than 100.

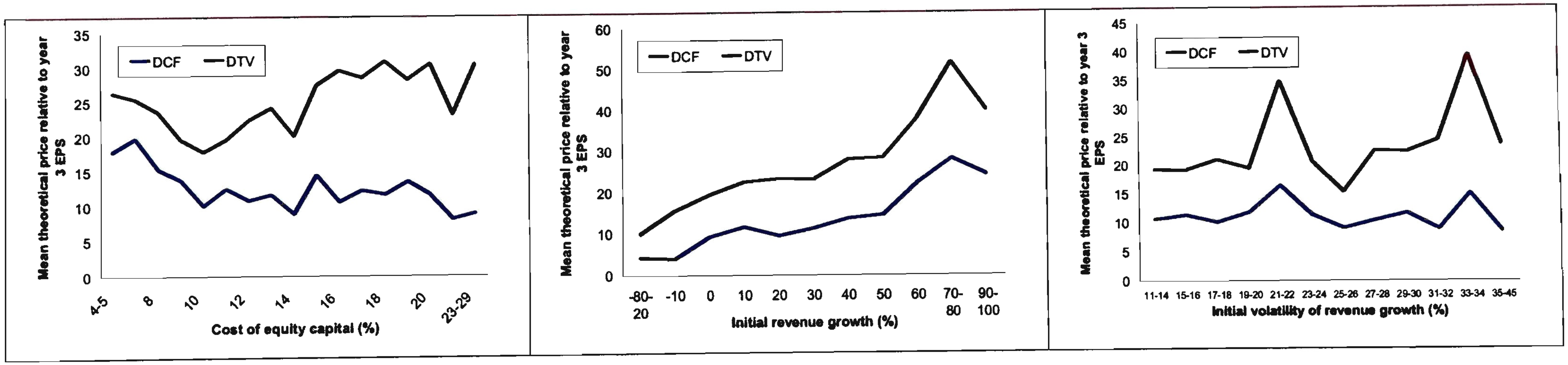


Figure 3.2

Price-earnings ratios amongst sub-samples partitioned on the basis of cost of equity capital, initial revenue growth and the initial volatility of revenue growth

Figure 2 illustrates the relationship between the mean ratio of theoretical price to year 3 forecast earnings per share and three variables – the cost of equity capital, initial revenue growth and the initial volatility of revenue growth. The data is drawn from a sub-sample of 454 firms with positive earnings forecasts, and whose theoretical price-earnings ratios are less than 100. The data is partitioned into 27 groups, based on the 33rd and 67th percentiles of the distribution of the cost of equity, initial growth and the volatility of growth.

Panel A: Price-earnings ratios relative to the cost of equity capital.

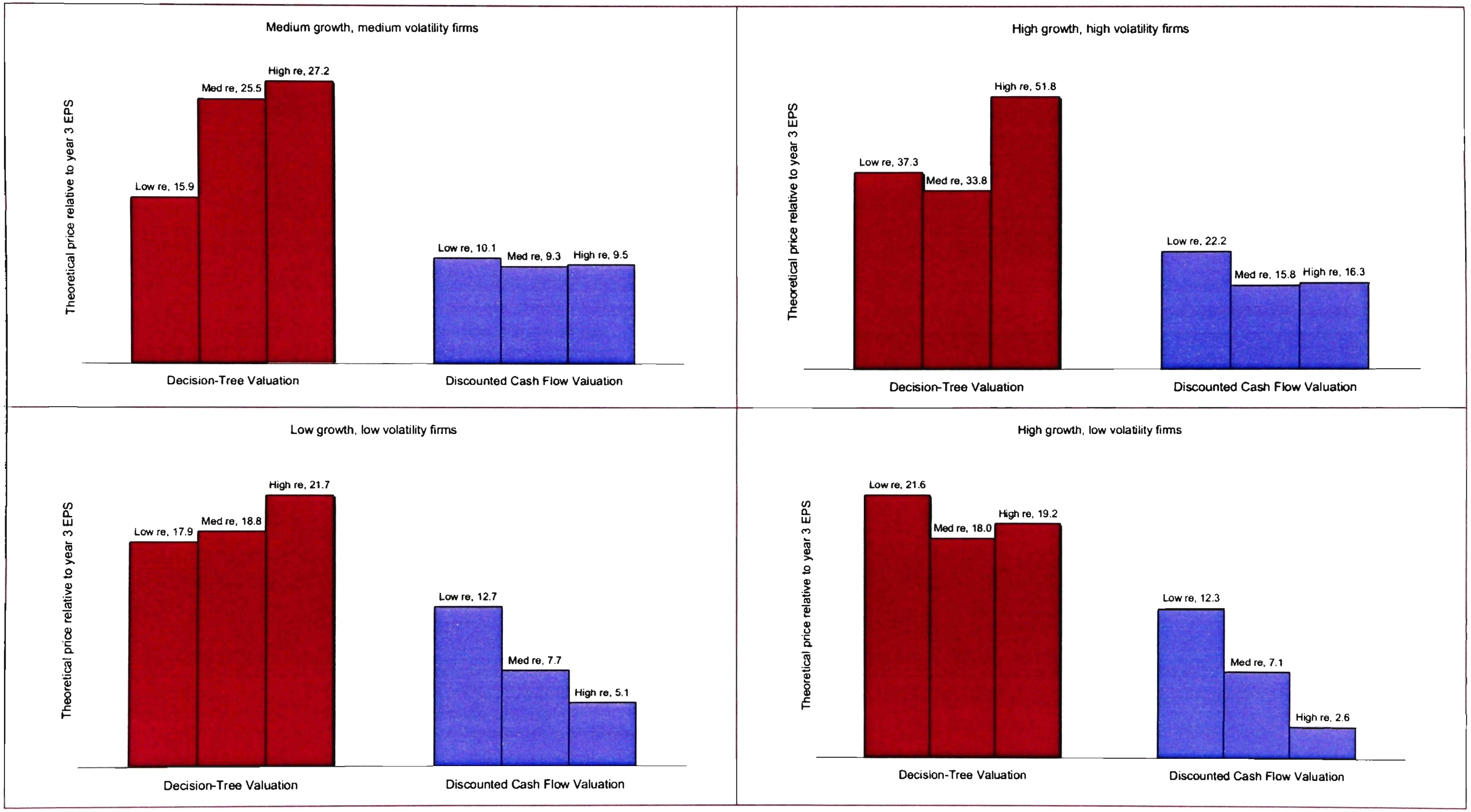


Figure 3.2
Price-earnings ratios amongst sub-samples partitioned on the basis of cost of equity capital, initial revenue growth and the initial volatility of revenue growth (continued)

Panel B: Price-earnings ratios relative to initial revenue growth

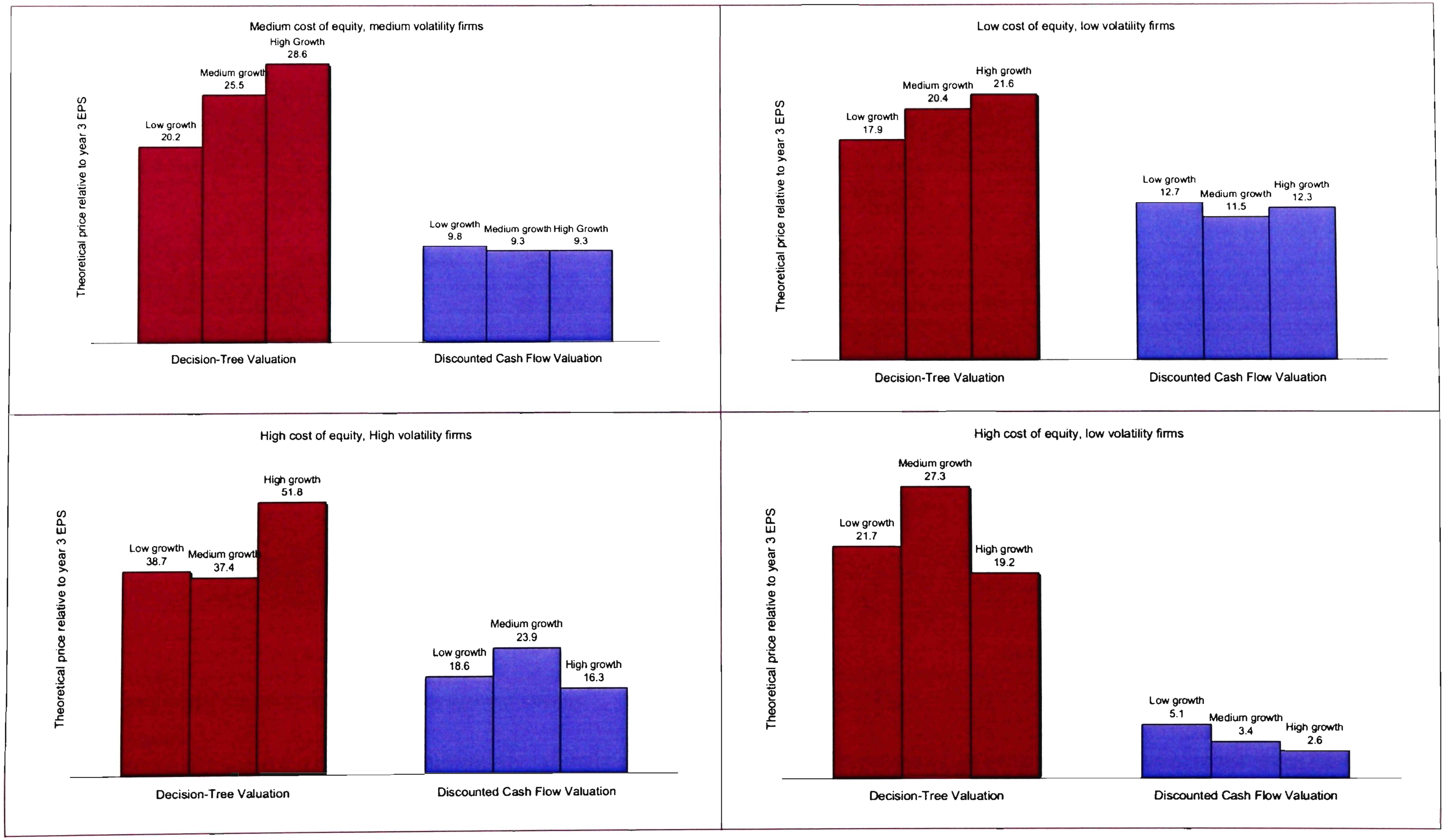
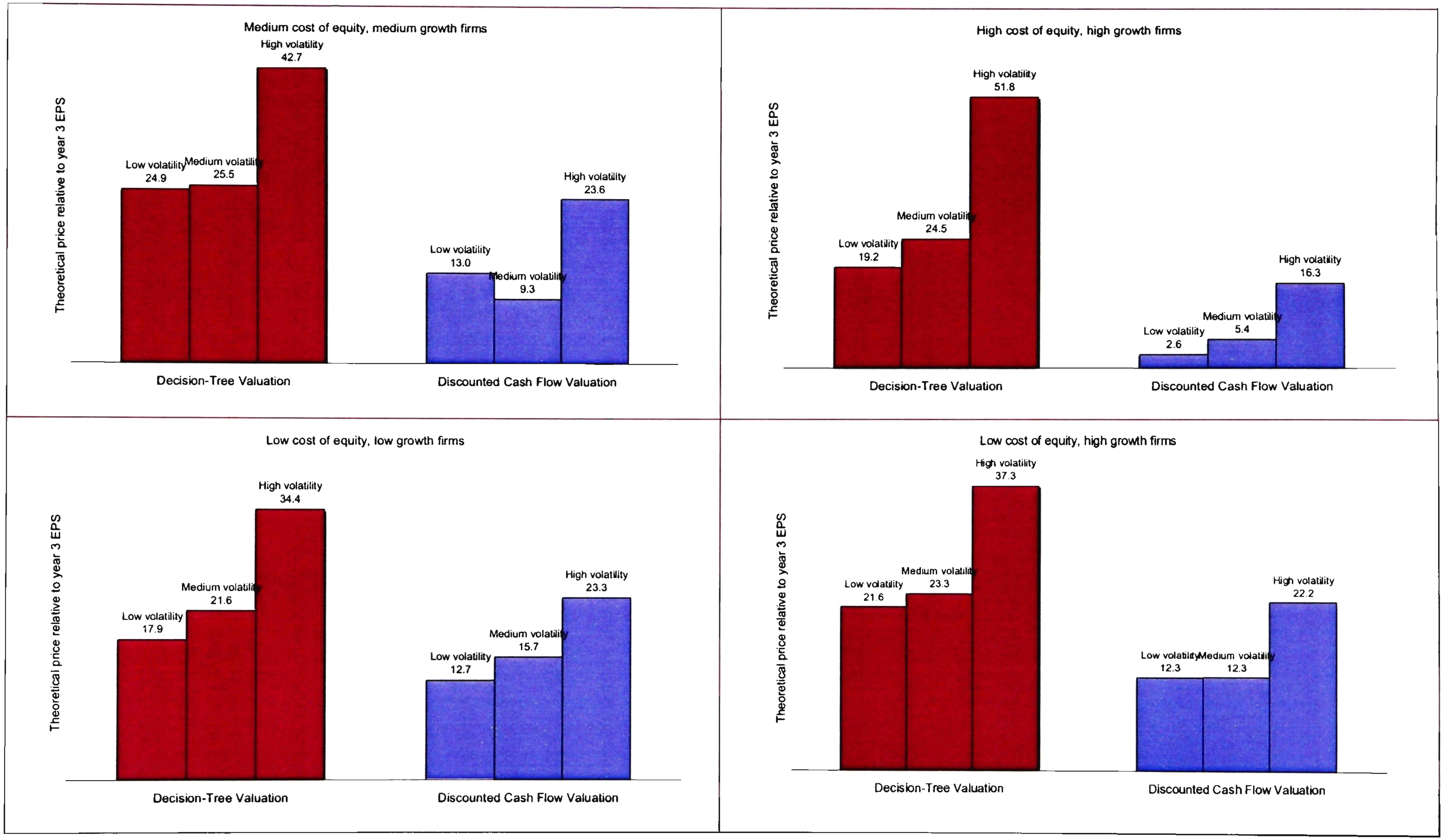


Figure 3.2
Price-earnings ratios amongst sub-samples partitioned on the basis of cost of equity capital, initial revenue growth and the initial volatility of revenue growth (continued)

Panel C: Price-earnings ratios relative to the initial volatility of revenue growth



5. Results

In a series of ordinary least regressions, I measure the association between *Real option%* and the initial return on a sample of IPOs. This analysis shows that *Real option%* is significantly and positively related to underpricing. The estimated coefficients range from 0.10 to 0.25 and the intercept term is insignificantly different from zero. These two results imply that, after controlling for underwriter and issuer incentives to engage in strategic underpricing, investors discount the value of embedded options by 10-25 percent when bidding for IPOs. For a firm with average *Real option%* of 47 percent, this predicts that investment bankers will price the IPO at a 5-12 percent discount to market value, in addition to any strategic underpricing. This discount can be attributed to information asymmetry between the issuer and investors, or amongst investors.

5.1. Primary results: *Real option%* and IPO underpricing

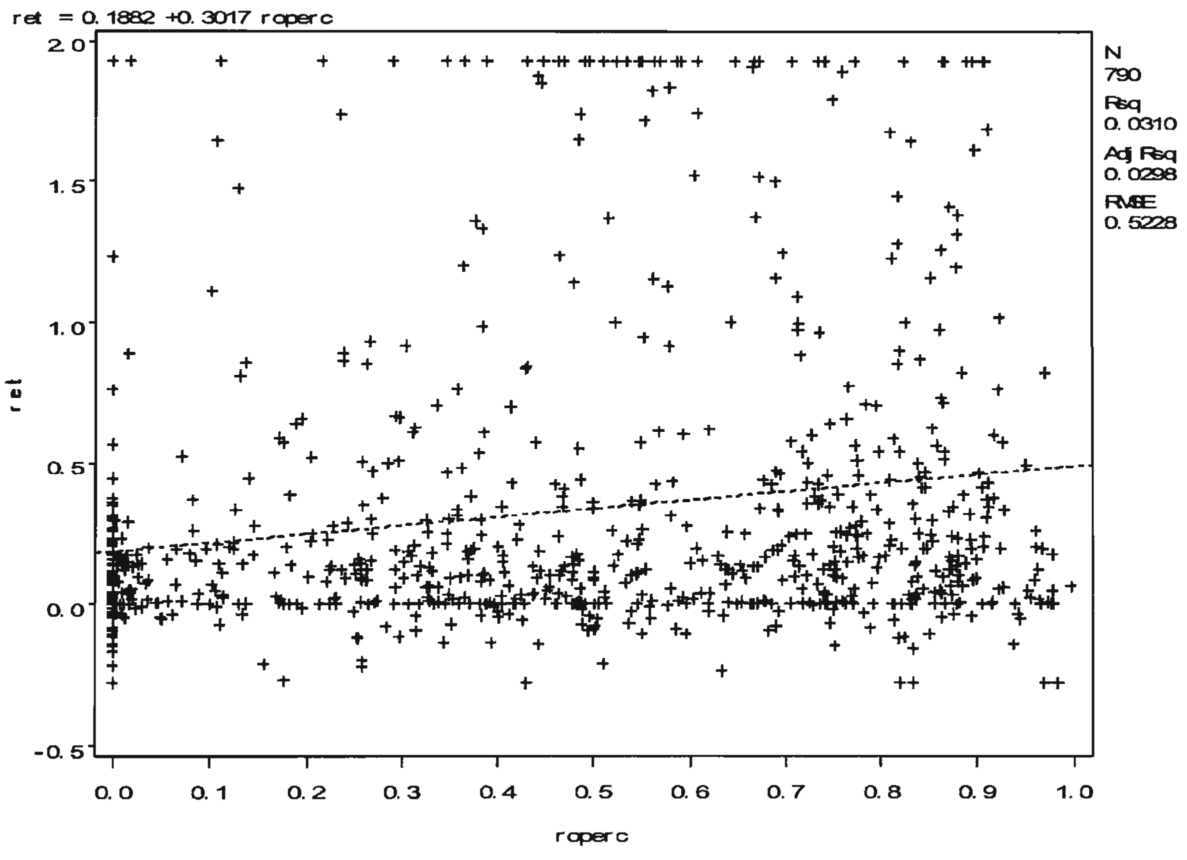
In Section 2, I documented the association between IPO underpricing and eight explanatory variables used by Ljungqvist and Wilhelm (2003) and Loughran and Ritter (2004). They were able to explain 45 and 29 percent of IPO underpricing respectively. In Table 3.5, I present the results of tests of association between those variables and the initial return. Panel A contains Pearson and Spearman correlation coefficients, while Panel B presents the results of simple linear regression in which the initial return is the dependent variable. The correlation matrix also contains data referring to variables which are used in later analysis.

The data in Panel B shows that *Real option%* can explain 3.0 percent of the variation in IPO underpricing. The coefficient of 0.30 on *Real option%* and the intercept term of 0.19 suggest that a typical IPO will have initial returns of 19-49 percent, depending on the proportion of equity value comprised of real options. Relying on equation 10, this implies that the *DCF* component of equity value is discounted by 16 percent $(\theta_1 = 0.84)$, while the value of embedded options is discounted by 37 percent $(\theta_2 = 0.63)$. This estimated discount can be attributed to both strategic and non-strategic underpricing, because the univariate analysis does not include controls for issuer and underwriter incentives. The univariate relationship is illustrated in Figure 3.

Heteroskedasticity was present in all regressions, so I performed significance tests on coefficients using White's adjusted *t*-statistics (White, 1980). The modelling presented in Section 4 shows an approximate linear relationship between *Real option%* and initial returns. For other variables in the regression equations, there is no theoretical linear relationship, but the use of these variables is standard practice in the literature. Initial returns were windsorized at the 1st and 95th percentiles, which mitigated the impact of a handful of extreme initial returns. This ensured that initial returns were approximately normally distributed, as were residuals. Throughout, there were no cases in which the Cook's D influence statistic was greater than 1, which implies that the results are not driven by outliers.

The other explanatory variables all exhibit a significant association with IPO underpricing, in the expected direction. *Price revision* has the highest explanatory power at 25.9 percent, which suggests that issue prices do not fully reflect investor demand for IPOs. This is consistent with the argument that underpricing is compensation for investors who reveal information by bidding higher prices for shares. Stocks issued during hot markets were relatively underpriced. The initial return of recent IPOs and the indicator variable for 1999-2000 IPOs were able to explain 19.2 and 18.4 percent of the variation in initial returns.

Figure 3.3
Relationship between *Real option%* and IPO underpricing



To measure the incremental explanatory power of *Real option%*, I ran several multivariate regressions, the first series of which is presented In Table 3.6. By incorporating controls for strategic underpricing, I am able to interpret the intercept term and the coefficient on *Real option%* as underpricing due to information asymmetry. Using equations 10 and 11, I can estimate the pricing discount on the *DCF* and Real option component of equity value. Models 1 and 3 include only the explanatory variables previously used in the literature, with model 1 excluding the Technology and Bubble indicator variables. Models 2 and 4 incorporate *Real option%* as a variable, so I its incremental explanatory power can be assessed.

Comparing models 1 and 2, there is evidence that underpricing is significantly associated with *Real option%*, with the coefficient of 0.10 significantly different from zero at the 1 percent level. In addition, the intercept term fell to 0.21 and is no longer significantly different from zero. These coefficients can be interpreted as the embedded option component of equity value being discounted by 10 percent by underwriters, in addition to any strategic underpricing ($\theta_1 = 1.00$; $\theta_2 = 0.90$).

This coefficient is economically significant. The mean issue size was $179 million and the mean initial return was 33.1 percent, which means that, on average $59 million was left on the table. Discounted Cash Flows contributed 53 percent to market value, and embedded options 47 percent. If the embedded option component of equity value is discounted by 10 percent, and the *DCF* component is fully valued, this implies that, on average, $11 million was left on the table for non-strategic reasons. Of course, this is just 19 percent of underpricing, but still equates to a difference in underwriter fees of nearly $1 million, assuming the typical 7 percent underwriting fee. This implies there are potentially material benefits to issuers and underwriters to efforts to reduce information asymmetry. This breakdown of offer price relative to market price is represented in Exhibit 3, where figures are expressed relative to a market price of $100.

Exhibit 3.3
Representative breakdown of IPO underpricing

	Market value	Multiple	IPO value
Discounted cash flows	$53	1.00	$53
Embedded options	47	0.90	42
Total equity value	100	0.95	95
Strategic discount			20
IPO price			75

However, the incremental explanatory power of the regression analysis is minimal. The addition of *Real option%* to models 3 and 4 increase he adjusted-R^2 by just 0.4 and 0.3 percent, respectively. This supports the view of Ritter and Welch (2002) that research into IPO allocation practices are most likely to result in improved understanding of IPO underpricing. Nevertheless, the information asymmetry explanation remains useful.

As a robustness check, I repeated the analysis after partitioning the sample into sub-samples, based on whether they were Technology stocks, and/or whether they were issued in 1999-2000. This is an alternative control for the indicator variables used in the full-sample regression. These results are presented in Table 3.7. Panel A presents results based on the

Technology/Non-technology and Bubble/Non-bubble partition. Panel B presents results derived from four sub-samples obtained after combining the two groups.

The results of Table 3.7 show that the coefficient on *Real option%* is not statistically significant for Technology stocks, but remains significant for IPOs issued during the hot issue market of 1999-2000. In contrast, the coefficient on the variable Overhang is largest and most significant for Technology stocks issued during this period. Overhang can be interpreted as a measure of issuer incentives to control underpricing. large, positive coefficient on overhang implies that issues in which only a small percentage of the firm was floated were severely underpriced. Perhaps the insignificant coefficient on *Real option%* for Technology stocks is due to the overwhelming strategic underpricing of these stocks. The large explanatory power of the regression on the Technology/Bubble sub-sample (43.8 percent) supports this explanation. Alternatively, there is no real association between *Real option%* and initial returns for technology stocks, or *Real option%* is measured with greatest uncertainty for these stocks.

The lack of statistical significance means that these competing explanations cannot be distinguished. But, it does raise the question as to whether *Real option%* is capturing a correlated omitted variable, and therefore cannot be interpreted in the way I have intended. In Sub-section 5.2, I address this issue.

Table 3.5
Univariate analysis

In Table 3.5, I present statistics which summarise the univariate relationship between IPO underpricing and several explanatory variables. Panel A shows correlation coefficients amongst the variables while Panel B summarises the simple linear regression results. The sample comprises 790 US IPOs which were issued from 1997-2004. The variables are defined as follows: *Initial return* is the discrete percentage difference between the offer price and the 1st-day closing price on the equity market; *Real option%* is the percentage difference between a *Decision-tree* and *DCF* valuation of equity, whose models are summarised in Exhibits 1 and 2; *Price revision* = IPO price/Mid-point of the filing range – 1; *Price revision*$^+$ = Maximum (*Price revision*, 0); *Overhang* = Shares retained by the issuer divided by shares issued; *Proceeds* is IPO price multiplied by issued shares; *Pre-issue IPO returns* is the average initial return for IPOs occurring in the 30 calendar days prior to the IPO; and *Pre-issue market returns* is the cumulative return on the S&P1500 Index for the 15 trading days prior to the IPO; *Technology* is an indicator variable for stocks in the IBES Industry Sector "Technology"; *Bubble* is an indicator variable for IPOs from 1999-2000; *Initial growth* revenue *(Growth)* is estimated as the mean revenue growth derived from the first three years of available IBES consensus forecasts subsequent to the IPO (fewer forecast years are used if three years of forecasts are not available); *Cost of equity* (r_e) is estimated using the Capital Asset Pricing Model, where the risk-free rate is the annualised yield on 10-year Treasury bonds at the listing date; the market risk premium is 6 percent; beta is estimated in a three-stage process where stage 1 is computing the coefficient from an ordinary least squares regression of monthly returns of the equity against the S&P1500 Super Index, stage 2 is multiplying this estimate by 2/3 and adding 1/3 (consistent with an adjustment made by Bloomberg) and stage 3 is constraining all beta estimates in the range 0 to 4; *High revenue growth, high* r_e and *high volatility* are indicator variables for those firms greater than or equal to the 67th percentile of the sample distribution, ranked on these variables.

Panel A: Correlation matrix (Pearson correlation, lower left; Spearman correlation, upper right)

Variable	Ret	RO%	Rev	Rev+	O/H	Size	IPO ret	Mkt ret	Tech	Bubb	Gr	r_e	Vol	HGr x RO%	Hr_e x RO%	HVol x RO%	Tech x RO%	Bubb x RO%
Initial return	---	0.20***	0.64***	0.49***	0.25***	0.14***	0.28***	0.12***	0.30***	0.31***	0.24***	0.32***	-0.07**	0.27***	0.31***	-0.13***	0.33***	0.37***
Real option%	0.18***	---	0.12***	0.13***	0.23***	-0.02	0.15***	-0.01	0.06	0.13***	-0.14***	0.31***	0.30***	0.08**	0.35***	0.42***	0.23***	0.38***
Revision (%)	0.51***	0.10***	---	0.73	0.16***	0.34***	0.25***	0.10***	0.17***	0.20***	0.13***	0.20***	-0.11***	0.16***	0.22***	-0.13***	0.20***	0.25***
Revision+ (%)	0.48***	0.12***	0.66***	---	0.18***	0.22***	0.22***	0.10***	0.20***	0.19***	0.15***	0.24***	-0.05	0.18***	0.22***	-0.10***	0.23***	0.24***
Overhang (Retained/issued)	0.23***	0.16***	0.10***	0.07***	---	-0.12***	0.17***	0.01***	0.23***	0.23***	0.13***	0.26***	-0.07*	0.21***	0.26***	-0.04	0.27***	0.27***
Size (In Proceeds)	0.08**	-0.03	0.29***	0.13***	-0.08**	---	0.12***	-0.06*	-0.10***	0.05	-0.09***	-0.01	0.11***	-0.02	0.05	0.00	-0.06*	0.05
Pre-issue IPO returns	0.44***	0.10***	0.28***	0.30***	0.08**	0.11***	---	-0.04	0.22***	0.81***	0.35***	0.33***	0.00	0.35***	0.28***	-0.12***	0.25***	0.73***
Pre-issue market returns	0.08**	0.01	0.09**	0.08**	0.01	-0.02	0.01	---	-0.01	-0.08**	-0.04	0.00	-0.13***	-0.01	-0.03	-0.05	0.00	-0.06*
Technology (1,0)	0.35***	0.07*	0.16***	0.20***	0.20***	-0.09***	0.24***	0.00	---	0.25***	0.21***	0.46***	-0.10***	0.14***	0.40***	-0.26***	0.92***	0.24***
Bubble (1999-2000=1,0)	0.43***	0.14***	0.19***	0.22***	0.15***	0.04	0.68***	-0.04	0.25***	---	0.40***	0.38***	-0.06*	0.42***	0.31***	-0.20***	0.27***	0.90***
Initial revenue growth	0.38***	-0.11***	0.10***	0.15**	0.10***	-0.12***	0.33***	-0.02	0.20***	0.41***	---	0.36***	0.13***	0.75***	0.25***	-0.03	0.14***	0.32***
Cost of equity capital	0.40***	0.29***	0.18***	0.27***	0.18***	-0.02	0.27***	-0.01	0.44***	0.37***	0.36***	---	-0.08**	0.37***	0.77***	-0.11***	0.48***	0.42***
Initial volatility of rev growth	-0.12***	0.31***	-0.16***	-0.08***	-0.12***	0.05	-0.11***	-0.11***	-0.19***	-0.14***	0.09**	-0.13***	---	0.13***	0.03	0.78***	-0.06*	0.03
High revenue growth x *RO%*	0.39***	0.21***	0.15***	0.19***	0.13***	-0.04	0.31***	0.00	0.09**	0.38***	0.68***	0.33***	0.19***	---	0.31***	0.03	0.14***	0.41***
High re x *Real option%*	0.31***	0.43***	0.21***	0.23***	0.17***	0.03	0.19***	-0.02	0.35***	0.27***	0.17***	0.70***	0.04	0.29***	---	-0.03	0.48***	0.38***
High volatility x *Real option%*	-0.16***	0.52***	-0.13***	-0.08**	-0.07**	-0.02	-0.14***	-0.05	-0.23***	-0.15***	-0.01	-0.05	0.77***	0.15***	0.08**	---	-0.21***	-0.08**
Technology x *Real option%*	0.37***	0.34***	0.20***	0.25***	0.22***	-0.04	0.23***	0.01	0.83***	0.23***	0.04	0.46***	-0.13***	0.07**	0.51***	-0.13***	---	0.30***
Bubble x *Real option%*	0.44***	0.47***	0.23***	0.25***	0.21***	0.03	0.55***	-0.02	0.20***	0.81***	0.24***	0.37***	-0.02	0.39***	0.39***	0.04	0.32***	---

Panel B: Simple linear regression

Explanatory variable	**Intercept**		**Explanatory variable**		**Adj-R^2**
	Coefficient	**p-value**	**Coefficient**	**p-value**	**(%)**
Real option%	0.19	(<0.01)	0.30	(<0.01)	3.0
Price revision (%)	0.46	(<0.01)	2.02	(<0.01)	25.9
Price revision$^+$ (%)	0.22	(<0.01)	4.89	(<0.01)	22.6
Overhang (Retained/issued)	0.23	(<0.01)	0.02	(<0.01)	5.1
Size (In proceeds)	-0.45	(0.17)	0.04	(0.02)	0.6
Pre-issue IPO returns	0.16	(<0.01)	0.21	(<0.01)	19.2
Pre-issue market returns	0.33	(<0.01)	1.06	(0.04)	0.4
Technology ("Technology" = 1)	0.20	(<0.01)	0.39	(<0.01)	12.0
Bubble (1999 or 2000 = 1)	0.13	(<0.01)	0.46	(<0.01)	18.4

Table 3.6
Regressions of percentage first-day returns on several variables

In Table 3.6, I present the results of the least squares regression of initial returns on several explanatory variables. The sample comprises 790 US IPOs which were issued from 1997-2004. The variables are defined as follows: *Initial return* is the discrete percentage difference between the offer price and the 1st-day closing price on the equity market; *Real option%* is the percentage difference between a *Decision-tree* and *DCF* valuation of equity, whose models are summarised in Exhibits 1 and 2; *Price revision* = IPO price/Mid-point of the filing range – 1; *Price revision*$^+$ = Maximum (*Price revision*, 0); *Overhang* = Shares retained by the issuer divided by shares issued; *Proceeds* is IPO price multiplied by issued shares; *Pre-issue IPO returns* is the average initial return for IPOs occurring in the 30 calendar days prior to the IPO; and *Pre-issue market returns* is the cumulative return on the S&P1500 Index for the 15 trading days prior to the IPO; *Technology* is an indicator variable for stocks in the IBES Industry Sector "Technology"; *Bubble* is an indicator variable for IPOs from 1999-2000; *Initial growth* revenue *(Growth)* is estimated as the mean revenue growth derived from the first three years of available IBES consensus forecasts subsequent to the IPO (fewer forecast years are used if three years of forecasts are not available); *Cost of equity* (r_e) is estimated using the Capital Asset Pricing Model, where the risk-free rate is the annualised yield on 10-year Treasury bonds at the listing date; the market risk premium is 6 percent; and beta is estimated in a three-stage process where stage 1 is computing the coefficient from an ordinary least squares regression of monthly returns of the equity against the S&P1500 Super Index, stage 2 is multiplying this estimate by 2/3 and adding 1/3 (consistent with an adjustment made by Bloomberg) and stage 3 is constraining all beta estimates in the range 0 to 4.

Explanatory variable	**Coefficients (*p*-values)**			
	Model 1	**Model 2**	**Model 3**	**Model 4**
Intercept	**0.60**	**0.52**	0.28	0.21
	(0.01)	**(0.02)**	(0.21)	(0.33)
Real option %	---	**0.12**	---	**0.10**
		(0.01)	---	**(0.01)**
Price revision	**1.21**	**1.20**	**1.19**	**1.18**
	(<0.01)	**(<0.01)**	**(<0.01)**	**(<0.01)**
Price revision$^+$	**1.82**	**1.77**	**1.57**	**1.53**
	(<0.01)	**(<0.01)**	**(<0.01)**	**(<0.01)**
Overhang (Retained/issued)	**0.02**	**0.01**	**0.01**	**0.01**
	(<0.01)	**(<0.01)**	**(0.01)**	**(0.01)**
Size (ln proceeds)	-0.02	-0.02	-0.01	-0.01
	(0.06)	(0.08)	(0.43)	(0.50)
Pre-issue IPO returns	**0.14**	**0.14**	**0.06**	**0.06**
	(<0.01)	**(<0.01)**	**(0.03)**	**(0.03)**
Pre-issue market returns	0.43	0.43	0.60	0.60
	(0.31)	(0.31)	(0.14)	(0.14)
Technology ("Technology" = 1)	---	---	**0.19**	**0.19**
			(<0.01)	**(<0.01)**
Bubble (1999 or 2000 = 1)	---	---	**0.21**	**0.20**
			(<0.01)	**(<0.01)**
Adjusted-R^2	40.0	40.4	44.7	45.0
N	790	790	790	790

Table 3.7
Sub-sample analysis: Technology issues and hot markets

I partitioned the sample into three sets of sub-samples, based on whether a stock was a Technology stock, whether it was issued during 1999-2000, and the four combinations of those groupings. I then repeated the analysis presented as model 4 in Table 3.6, removing indicator variables where appropriate. The sample comprises 790 US IPOs from 1997-2004.

The variables are defined as follows: *Initial return* is the discrete percentage difference between the offer price and the 1st-day closing price on the equity market; *Real option%* is the percentage difference between a *Decision-tree* and *DCF* valuation of equity, whose models are summarised in Exhibits 1 and 2; *Price revision* = IPO price/Mid-point of the filing range – 1; *Price revision$^+$* = Maximum (*Price revision*, 0); *Overhang* = Shares retained by the issuer divided by shares issued; *Proceeds* is IPO price multiplied by issued shares; *Pre-issue IPO returns* is the average initial return for IPOs occurring in the 30 calendar days prior to the IPO; and *Pre-issue market returns* is the cumulative return on the S&P1500 Index for the 15 trading days prior to the IPO; *Technology* is an indicator variable for stocks in the IBES Industry Sector "Technology"; *Bubble* is an indicator variable for IPOs from 1999-2000; *Initial growth* revenue *(Growth)* is estimated as the mean revenue growth derived from the first three years of available IBES consensus forecasts subsequent to the IPO (fewer forecast years are used if three years of forecasts are not available); *Cost of equity (r_e)* is estimated using the Capital Asset Pricing Model; where the risk-free rate is the annualised yield on 10-year Treasury bonds at the listing date; the market risk premium is 6 percent; and beta is estimated in a three-stage process where stage 1 is computing the coefficient from an ordinary least squares regression of monthly returns of the equity against the S&P1500 Super Index, stage 2 is multiplying this estimate by 2/3 and adding 1/3 (consistent with an adjustment made by Bloomberg) and stage 3 is constraining all beta estimates in the range 0 to 4.

Panel A: Sample partitioned into two groups according to whether they were technology versus non-technology stocks or 1999-2000 issues versus 1997-98, 2001-04 issues

Explanatory variable	**Coefficients (*p*-values)**			
	Technology IPOs	**Non-tech IPOs**	**1999-2000 IPOs**	**1997-98, 2001-04 IPOs**
Intercept	0.01	**0.43**	0.79	0.14
	(0.99)	**(0.02)**	(0.13)	(0.36)
Real option %	0.09	**0.11**	**0.17**	**0.05**
	(0.37)	**(0.01)**	**(0.07)**	**(0.07)**
Price revision	**1.93**	**0.88**	**2.21**	**0.52**
	(<0.01)	**(<0.01)**	**(<0.01)**	**(<0.01)**
Price revision$^+$	0.81	**1.34**	0.64	**0.82**
	(0.28)	**(<0.01)**	(0.32)	**(0.07)**
Overhang (Retained/issued)	**0.02**	0.01	**0.02**	0.00
	(<0.01)	(0.33)	**(0.01)**	(0.56)
Size (ln proceeds)	0.01	**-0.02**	-0.03	0.00
	(0.81)	**(0.08)**	(0.30)	(0.97)
Pre-issue IPO returns	**0.06**	0.03	0.04	-0.08
	(0.08)	(0.55)	(0.19)	(0.18)
Pre-issue market returns	**1.54**	0.05	0.78	**0.55**
	(0.04)	(0.91)	(0.26)	**(0.03)**
Technology ("Technology" = 1)	---	---	**0.33**	**0.05**
			(<0.01)	**(0.01)**
Bubble (1999 or 2000 = 1)	**0.41**	**0.15**	---	---
	(<0.01)	**(0.03)**		
Adjusted-R^2	51.6	27.2	41.8	25.6
N	264	526	349	441

Panel B: Sample partitioned into four groups according to whether they were technology versus non-technology stocks and 1999-2000 issues versus 1997-98, 2001-04 issues

Explanatory variable	**Coefficients (*p*-values)**			
	1999-2000 Technology IPOs	**1999-2000 Non-tech IPOs**	**1997-98, 2001-04 Technology IPOs**	**1997-98, 2001-04 Non-tech IPOs**
Intercept	0.00	**1.25**	0.34	0.08
	(1.00)	**(<0.01)**	(0.24)	(0.67)
Real option %	0.12	**0.19**	0.01	**0.04**
	(0.52)	**(0.08)**	(0.96)	**(0.07)**
Price revision	**2.63**	**1.80**	**0.69**	**0.48**
	(<0.01)	**(<0.01)**	**(<0.01)**	**(<0.01)**
Price revision$^+$	0.28	0.64	0.97	0.39
	(0.78)	(0.37)	(0.23)	(0.38)
Overhang (Retained/issued)	**0.03**	0.01	0.00	**0.01**
	(<0.01)	(0.49)	(0.76)	**(0.08)**
Size (ln proceeds)	0.03	**-0.05**	-0.01	0.00
	(0.68)	**(0.03)**	(0.61)	(0.78)
Pre-issue IPO returns	0.05	0.02	0.02	-0.09
	(0.18)	(0.64)	(0.81)	(0.22)
Pre-issue market returns	1.46	0.01	**1.53**	0.34
	(0.14)	(0.99)	**(0.01)**	(0.22)
Adjusted-R^2	43.8	23.5	31.3	19.2
N	162	187	102	339

5.2. Interaction with cost of capital, revenue growth and volatility

Real option% is primarily a function of the cost of equity, initial revenue growth and the initial volatility of revenue growth. These variables on their own have the potential to explain IPO underpricing, because they arguably proxy for information asymmetry. But *Real option%* combines these variables in economically meaningful way. As I established in Section 3, there is an approximately linear relationship between IPO underpricing and *Real option%*. But there is not necessarily a linear relationship between IPO underpricing and other proxies for information asymmetry.

Nevertheless, there is the potential for these parameters to capture some undefined economic construct which has contaminated the result. I control for this potential in two ways. First, I repeat my analysis after partitioning the sample into sub-samples, based on initial revenue growth, the cost of equity and the initial volatility of revenue growth. Second, I use these variables as controls in the regression analysis, and also include interaction terms. The results generally support those presented in Tables 6 and 7, but increase the explanatory power to 51.2 percent. This supports the primary conclusion of this study – that IPO offer prices incorporate a 10 percent discount on the value of embedded options, in addition to any strategic underpricing.

Table 3.8, Panel A presents the results for three sub-samples formed for equally-sized sub-samples formed on the basis of revenue growth, the cost of equity and volatility of revenue growth. The results for initial growth partition suggests that *Real option%* is most important for high-growth firms, although its coefficient remains significant throughout. For high-growth firms, its coefficient of 0.35 is significantly greater than the coefficients for the other groups. There are also stronger relationships between underpricing and other explanatory variables and a significantly negative intercept term. Note that the negative intercept term does not imply that mean predicted underpricing is negative for this period. Its impact is countered by the significantly positive intercept term on size. It is also attributable to the fact that the high-growth sub-sample is predominantly drawn from the hot issue market of 1999-2000. IPOs from this period had mean initial growth estimates of 50 percent, compared to 23 percent for the rest of the sample. During this period, the regression variables were very large, compared to the other periods. So, when they are applied to the model coefficients, predicted underpricing is positive.

In contrast, when I partitioned the sample of the basis of initial volatility, the coefficient on *Real option%* is highest for the low-volatility group. It is not significantly different from zero for the other groups, and it produces the largest increase in explanatory power for the low volatility group (an increase of 1.7 percent). However, for the medium-volatility group, note the magnitude of the coefficients on *Price revision, Overhang* and *Pre-issue market returns*, and the adjusted-R^2 of 54.1 percent. It is likely that any explanatory power of *Real option%* is swamped by large strategic underpricing for this sample. In other words, for this sub-sample there is evidence of large, strategic underpricing where a fraction of the firm is sold (as measured by *Overhang*) or during hot markets (as captured by *Pre-issue market returns*). This strategic underpricing is likely to have a far greater impact on initial returns than information asymmetry.

My primary concern is the insignificant coefficient for the high-volatility sub-sample. I consider the most likely explanation to be due to measurement error. High-volatility firms have a higher *Real option%*, but that does not imply that the value of their embedded options will be priced differently by underwriters. Hence, there is no theoretical reason to expect a relationship between volatility of growth and the coefficient on *Real option%*. However, the estimation error inherent in this variable will be largest for the high-volatility group.

In sum, the sub-sample analysis suggests that the coefficient on *Real option%* is directly related to the magnitude of revenue growth, and inversely related to the volatility of revenue growth. However, it is inconclusive whether this is due to firm characteristics, or simply due to a change in strategic underpricing that occurred in the hot issue market of 1999-2000. Regardless, the coefficient on *Real option%* was significantly positive in five of the nine partitions, and had the expected sign throughout.

I also repeated the analysis after directly including revenue growth, the cost of equity and initial volatility as explanatory variables. My intent is to determine whether *Real option%* is remains associated with IPO underpricing, even if its underlying parameters – cost of equity, revenue growth and volatility – capture some other economic construct. The results of this analysis, presented as the first model in Panel B, show that explanatory power is enhanced by including these variables. The adjusted-R^2 increases to 48.4 percent, which is a 3.7 percent improvement on the results presented in Table 3.6 (model 3). However, once *Real option%* is included as an explanatory variable, explanatory power increases by a further 0.6. percent. This improvement is small, but of the same magnitude as observed in earlier results. This implies that *Real option%* is still associated with IPO underpricing, even if its underlying parameters represent a correlated omitted variable.

The coefficient on initial volatility is significantly negative, which is unlikely to result from multicollinearity (its correlation with *Real option%* is 0.31). This implies that, for two firms with the same volatility of revenue growth, the firm with the higher proportion of value comprised of embedded options was priced at the deepest discount. By the same token, for two firms with the same proportion of value comprised of embedded options, the firm with the higher volatility of revenue growth was priced at a premium. We are unable to say with any certainty what volatility is actually capturing, and regardless of its economic interpretation, the primary result of this paper remains valid. However, the modelling which underlies *Real option%* provides one interpretation, based on the competitive advantage period.

In order for two firms to have the same *Real option%*, but different initial volatility of revenue growth, one of their other parameters must be different. After volatility, the next most influential parameter which determines *Real option%* is the competitive advantage period. So, all else being equal, the lower volatility firm has the higher assumed *CAP* and less underpricing. In other words, firms whose market value factors in a longer period of above-average revenue growth and profitability are more fully-priced. This explanation is not conclusive by any means. In the modelling used here, *CAP* cannot be determined independently from *Real option%*, and we cannot completely eliminate the multicollinearity explanation. It is simply a potential explanation which can be explored in further work, and which in no way diminishes the primary result.

The remaining models presented in Table 3.8 assess the impact of interaction terms. *Real option%* interacts with indicator variables which take on a values of one if the firm is in the high-growth, high-cost of equity or high-volatility third of the sample. It also interacts with the indicator variables for Technology and 1999-2000 IPOs. We observe further improvements in explanatory power in these models and the coefficient on *Real option%* remains significantly positive. I do not separately interpret the coefficients on the interaction terms in these models, as their correlation coefficients against *Real option%* approach 0.5. However, the interaction terms and *Real option%* were jointly different from zero at less than the one percent significance level.

I also note that the highest explanatory power is achieved when *Real option%* interacts with the *Technology* and *Bubble* indicator variables (adjusted-R^2 = 51.2 percent compared to 50.4 percent). This provides further support for the use of *Real option%* as an economic construct. In model (3) of Panel B, the coefficients on Technology and Bubble are 0.13 and 0.08, which are consistent with prior research and represent the non-strategic component of underpricing of these stocks. But explanatory power of those variables increases when they interact with *Real option%*. This suggests that the non-strategic IPO underpricing which occurred in the tech bubble can be partially attributed to an increase in the option component of equity value.

Finally, I performed the following analysis to alleviate any residual concerns that the results are driven by a mechanical association between initial return and *Real option%*. Recall that *Real option%* is estimated after calibrating the *Decision-tree* valuation to market price. Using the same competitive advantage period which minimises the difference between *Decision-tree* value and market price, I estimate the *DCF* value. I attribute the difference between the *Decision-tree* and *DCF values* to the value of embedded options. So, there are two close parameters (*1st-day close* and *Decision-tree* value) which appear on both sides of the regression equation. However, *Real option%* is estimated completely independently of the offer price, so there is no mechanical association. The calibration is simply used to determine the appropriate competitive advantage period assumption for the *DCF* valuation. This is entirely appropriate for the research question at hand, just as it would have been entirely inappropriate for the study presented in Chapter 2. In an evaluation of portfolio performance, it was important to use only information available to form investment portfolios.

Nevertheless, I repeated the analysis after including all 57 estimates of *Real option%*, after assuming their competitive advantage period ranges from 4 to 60 years. To simply use the same *CAP* assumption for all firms reduces the dispersion of *Real option%* across firms. It will overstate *Real option%* for firms whose revenue growth and profit margin are already close to long-term values; and understate *Real option%* for less mature firms.

The multicollinearity resulting from the inclusion of all 57 estimates of *Real option%* means that the coefficients cannot be separately interpreted. But they were jointly different from zero at less than the 1 percent level. Furthermore, the adjusted-R^2 increased to 46.9 percent, from the 45.0 percent reported as model 4 in Table 3.6. These results are presented in Table 3.9. The second model shown in that table is the regression model with the highest adjusted-R^2. That model includes all 57 estimates of *Real option%*, as well as their interaction with high revenue growth and high-volatility firms. The highest adjusted-R^2 achieved was 52.5 percent.

5.3. Results conclusion and comparison of coefficients

The evidence presented in this paper suggests that the embedded option component of equity value is discounted by about 10 percent when setting offer prices, in addition to any strategic underpricing. I conclude this section with a comparison of my results to those of Ljungqvist and Wilhelm (2003) and Loughran and Ritter (2004). These studies were able to explain up to 46.0 and 29.0 percent of underpricing, respectively. I report higher adjusted-R^2 figures than these authors, but the difference in explanatory power could simply be due to sample differences. What is more relevant is a comparison of the coefficients which are common to my study and those of previous studies. The coefficients I refer to are drawn from Table 3.6

and the first two models of Table 3.8. The comparison coefficients are drawn from Table 3.6 of Ljungqvist and Wilhelm and Table 3.5 of Loughran and Ritter. That comparison can be summarised as follows:

- *Technology*: Results are consistent between my paper and prior research and there remains some unexplained underpricing of technology stocks. Ljungqvist and Wilhelm report a coefficient of 0.05-0.06 on high-tech stocks and 0.15-0.23 on internet stocks, while Loughran and Ritter corresponding coefficients of 0.06 and 0.34-0.35. I report a coefficient of 0.13-0.19 on Technology. Hence, there remains some underpricing of Technology stocks which is unexplained. However, explanatory power increases when this variable interacts with *Real option%.*

- *Bubble* (1999-2000 IPOs): Results are consistent between my paper and prior research and there remains some unexplained underpricing of IPOs during 1999-2000. My results include a coefficient on Bubble of 0.10-0.21, which spans the range of 0.14-0.15 reported by Ljungqvist and Wilhelm but exceeds the 0.07 reported by Loughran and Ritter (which was not significant).

- *Overhang:* My coefficient on overhang of 0.01 is well below the 0.04 reported by Loughran and Ritter. I can only attribute this to sampling differences or the windsorizing of returns at the 95^{th} percentile. The results hold even when these returns are included.

- *Price revision* and *Price revision*$^{+}$: Results are consistent between my paper and prior research, although my estimated coefficients are larger. Specifically, *Price revision* is the dominant predictor of IPO underpricing. I report coefficients of 1.14-1.19 on *Price Revision* and 1.29-1.57 on *Price revision*$^{+}$ These are well above the estimates of 0.42-0.43 and 0.89 reported by Ljungqvist and Wilhelm . This is potentially due to a difference in the date at which the indicative filing range was recorded. I used the indicative range provided to the SEC closest to the offer date and report mean revisions of -6.4 percent, while Ljungqvist and Wilhelm report mean revisions of 5.8 percent. This difference is especially prominent for 1999-2000 IPOs.

- S*ize:* There is further evidence to that *Real option%* measures information asymmetry. When *Real option%* is included as an explanatory variable, there is no longer any relationship between size and IPO underpricing. In contrast, Loughran and Ritter report and negative relationship between ln (Assets) and underpricing. These results provide further support for the interpretation of *Real option%* as a measure of information asymmetry.

Table 3.8
Interaction of *Real option%* with risk, growth and volatility

I partitioned the sample into three sets of sub-samples, based on the 33rd and 67th percentiles of estimates for initial revenue growth, the initial volatility of revenue growth and the cost of equity capital. I then repeated the analysis presented as model 4 in Table 3.6. These results are presented in Panel A. In Panel B, I include terms which interact with *Real option%*. High-volatility, high-cost of equity and high-growth firms are those at the 67th percentile or above of the sample distribution. I also allow the *Technology* and *Bubble* indicator variables to interact with *Real option%*. These results are presented in Panel B. The sample comprises 790 US IPOs from 1997-2004.

The variables are defined as follows: *Initial return* is the discrete percentage difference between the offer price and the 1st-day closing price on the equity market; *Real option%* is the percentage difference between a *Decision-tree* and *DCF* valuation of equity, whose models are summarised in Exhibits 1 and 2; *Price revision* = IPO price/Mid-point of the filing range – 1; *Price revision*$^+$ = Maximum (*Price revision*, 0); *Overhang* = Shares retained by the issuer divided by shares issued; *Proceeds* is IPO price multiplied by issued shares; *Pre-issue IPO returns* is the average initial return for IPOs occurring in the 30 calendar days prior to the IPO; and *Pre-issue market returns* is the cumulative return on the S&P1500 Index for the 15 trading days prior to the IPO; *Technology* is an indicator variable for stocks in the IBES Industry Sector "Technology"; *Bubble* is an indicator variable for IPOs from 1999-2000; *Initial growth* revenue *(Growth)* is estimated as the mean revenue growth derived from the first three years of available IBES consensus forecasts subsequent to the IPO (fewer forecast years are used if three years of forecasts are not available); *Cost of equity* (r_e) is estimated using the Capital Asset Pricing Model; where the risk-free rate is the annualised yield on 10-year Treasury bonds at the listing date; the market risk premium is 6 percent; and beta is estimated in a three-stage process where stage 1 is computing the coefficient from an ordinary least squares regression of monthly returns of the equity against the S&P1500 Super Index, stage 2 is multiplying this estimate by 2/3 and adding 1/3 (consistent with an adjustment made by Bloomberg) and stage 3 is constraining all beta estimates in the range 0 to 4.

Panel A: Sample partitioned on the basis of cost of equity capital, initial revenue growth and the initial volatility of revenue growth

Explanatory variable	Coefficients (p-values)								
	Initial growth partition			Cost of equity partition			Initial volatility partition		
	Low growth	Medium growth	High growth	Low r_e	Medium r_e	High r_e	Low vol	Medium vol	High vol
Intercept	0.24	0.48	**-2.16**	0.04	0.33	0.94	**0.78**	-0.54	0.21
	(0.14)	(0.18)	**(0.01)**	(0.87)	(0.28)	(0.13)	**(<0.01)**	(0.43)	(0.50)
Real option%	**0.09**	**0.13**	**0.35**	0.01	**0.20**	0.04	**0.19**	0.09	0.01
	(0.04)	**(0.01)**	**(0.01)**	(0.77)	**(0.10)**	(0.74)	**(<0.01)**	(0.45)	(0.92)
Price revision	**0.59**	**0.99**	**1.57**	**0.75**	**0.88**	**1.86**	**1.19**	**2.19**	**0.55**
	(<0.01)	**(<0.01)**	**(<0.01)**	**(<0.01)**	**(<0.01)**	**(<0.01)**	**(<0.01)**	**(<0.01)**	**(<0.01)**
Price revision$^+$	1.05	1.03	**1.16**	0.37	**2.64**	0.43	**1.10**	0.74	**1.22**
	(0.17)	(0.17)	**(0.10)**	(0.64)	**(0.01)**	(0.49)	**(0.03)**	(0.42)	**(0.10)**
Overhang	0.01	**0.01**	0.01	0.01	**0.01**	**0.01**	0.00	**0.03**	0.02
(Retained/issued)	(0.12)	**(0.05)**	(0.26)	(0.23)	**(0.05)**	**(0.03)**	(0.45)	**(<0.01)**	(0.13)
Size (ln proceeds)	-0.01	-0.02	**0.12**	0.00	-0.02	-0.05	**-0.04**	0.04	-0.01
	(0.19)	(0.26)	**(0.01)**	(0.74)	(0.26)	(0.18)	**(0.09)**	(0.29)	(0.66)
Pre-issue IPO returns	0.02	0.02	0.04	-0.07	**0.12**	0.06	0.02	0.05	0.10
	(0.59)	(0.73)	(0.20)	(0.37)	**(0.01)**	(0.15)	(0.76)	(0.16)	(0.26)
Pre-issue market	**1.33**	0.35	0.59	-0.23	0.49	**1.86**	0.16	**1.40**	-0.31
returns	**(0.01)**	(0.53)	(0.46)	(0.61)	(0.41)	**(0.03)**	(0.79)	**(0.07)**	(0.54)
Technology	**0.10**	**0.13**	**0.29**	**0.12**	0.06	**0.19**	**0.07**	0.05	0.00
("Technology" = 1)	**(0.03)**	**(<0.01)**	**(<0.01)**	**(0.04)**	(0.25)	**(<0.01)**	**(0.08)**	(0.70)	(0.87)
Bubble	**0.11**	**0.12**	**0.22**	**0.19**	0.07	**0.33**	**0.16**	**0.34**	0.08
(1999 or 2000 = 1)	**(0.07)**	**(0.09)**	**(<0.01)**	**(0.07)**	(0.33)	**(<0.01)**	**(0.07)**	**(0.01)**	(0.40)
Adjusted-R^2	29.8	43.0	47.3	19.0	44.5	42.0	29.1	54.1	27.8
Adj-R^2 excluding *Real option%*	28.9	42.1	46.2	19.3	43.1	42.2	27.4	54.2	28.1
N	261	268	261	261	268	261	281	239	270

Table 3.8
Interaction of *Real option%* with risk, growth and volatility (continued)

Panel B: Interaction of growth, risk and volatility with Real option%

Explanatory variable	Coefficients (*p*-values)				
	Risk, growth and volatility	***Real option%***	**Interaction of *Real option%* with risk, growth and vol**	**Interaction of *Real option%* with Tech and Bubble**	**All variables**
Intercept	-0.12	-0.21	-0.31	-0.24	-0.24
	(0.64)	(0.43)	(0.26)	(0.37)	(0.36)
Real option %	---	**0.17**	**0.25**	**0.10**	**0.10**
		(<0.01)	**(<0.01)**	**(0.07)**	**(0.08)**
Price revision	**1.19**	**1.14**	**1.14**	**1.15**	**1.14**
	(<0.01)	**(<0.01)**	**(<0.01)**	**(<0.01)**	**(<0.01)**
Price revision$^+$	**1.29**	**1.32**	**1.22**	**1.11**	**1.10**
	(<0.01)	**(<0.01)**	**(<0.01)**	**(<0.01)**	**(0.01)**
Overhang (Retained/issued)	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
	(0.01)	**(0.03)**	**(0.04)**	**(0.04)**	**(0.05)**
Size (ln proceeds)	0.00	0.01	0.01	0.00	0.00
	(0.82)	(0.40)	(0.60)	(0.72)	(0.69)
Pre-issue IPO returns	**0.06**	**0.05**	**0.05**	**0.05**	**0.05**
	(0.04)	**(0.04)**	**(0.06)**	**(0.04)**	**(0.05)**
Pre-issue market returns	**0.64**	0.57	0.59	0.58	0.58
	(0.10)	(0.15)	(0.13)	(0.13)	(0.14)
Technology ("Technology" = 1)	**0.13**	**0.14**	**0.13**	---	0.02
	(<0.01)	**(<0.01)**	**(<0.01)**		(0.68)
Bubble (1999 or 2000 = 1)	**0.12**	**0.10**	**0.08**	---	-0.04
	(0.01)	**(0.02)**	**(0.06)**		(0.51)
Initial revenue growth	**0.28**	**0.34**	**0.22**	**0.25**	**0.26**
	(<0.01)	**(<0.01)**	**(<0.01)**	**(<0.01)**	**(<0.01)**
Cost of equity capital	**1.10**	**0.70**	**0.99**	**1.21**	**1.22**
	(<0.01)	**(0.05)**	**(0.03)**	**(0.01)**	**(0.01)**
Initial volatility of rev growth	0.02	**-0.30**	**0.45**	**0.44**	**0.43**
	(0.93)	**(0.10)**	**(0.05)**	**(0.05)**	**(0.06)**
High revenue growth x *Real option%*	---	---	**0.24**	**0.22**	**0.22**
			(0.01)	**(0.02)**	**(0.02)**
High re x *Real option%*	---	---	-0.08	**-0.15**	**-0.15**
			(0.26)	**(0.04)**	**(0.04)**
High volatility x *Real option%*	---	---	**-0.29**	**-0.25**	**-0.26**
			(<0.01)	**(<0.01)**	**(<0.01)**
Technology x *Real option%*	---	---	---	**0.27**	**0.24**
				(<0.01)	**(0.01)**
Bubble x *Real option%*	---	---	---	**0.20**	**0.25**
				(<0.01)	**(<0.01)**
Adjusted-R^2	48.4	49.0	50.4	51.2	51.1
N	790	790	790	790	790

Table 3.9

Inclusion of *Real option%* under competitive advantage period assumptions from 4 to 60 years

For all firms, I made 57 estimates of *Real option%* under the assumption that the competitive advantage period takes on integer values from 4 to 60 years. I then included all estimates for *Real option%* in the regression model, whose results are presented in the first model below. The coefficients on the estimates for *Real option%* cannot be separately interpreted, due to multicollinearity, but were jointly different from zero. I also incorporated the interaction of all estimates of *Real option%* with indicator variables for high-growth and high-volatility firms. These firms are those ranked at the 67th percentile or above of the sample distribution. These regression results are presented in Panel B. The sample comprises 790 US IPOs from 1997-2004.

The variables are defined as follows: *Initial return* is the discrete percentage difference between the offer price and the 1st-day closing price on the equity market; *Real option%* is the percentage difference between a *Decision-tree* and *DCF* valuation of equity, whose models are summarised in Exhibits 1 and 2; *Price revision* = IPO price/Mid-point of the filing range – 1; *Price revision*$^+$ = Maximum (*Price revision*, 0); *Overhang* = Shares retained by the issuer divided by shares issued; *Proceeds* is IPO price multiplied by issued shares; *Pre-issue IPO returns* is the average initial return for IPOs occurring in the 30 calendar days prior to the IPO; and *Pre-issue market returns* is the cumulative return on the S&P1500 Index for the 15 trading days prior to the IPO; *Technology* is an indicator variable for stocks in the IBES Industry Sector "Technology"; *Bubble* is an indicator variable for IPOs from 1999-2000; *Initial growth* revenue *(Growth)* is estimated as the mean revenue growth derived from the first three years of available IBES consensus forecasts subsequent to the IPO (fewer forecast years are used if three years of forecasts are not available); *Cost of equity* (r_e) is estimated using the Capital Asset Pricing Model; where the risk-free rate is the annualised yield on 10-year Treasury bonds at the listing date; the market risk premium is 6 percent; and beta is estimated in a three-stage process where stage 1 is computing the coefficient from an ordinary least squares regression of monthly returns of the equity against the S&P1500 Super Index, stage 2 is multiplying this estimate by 2/3 and adding 1/3 (consistent with an adjustment made by Bloomberg) and stage 3 is constraining all beta estimates in the range 0 to 4.

Explanatory variable	**Coefficients (*p*-values)**	
	Inclusion of all *Real option%*	**Maximum adj-R^2 regression**
Intercept	0.05 (0.87)	-0.17 (0.65)
Real option %	**All *Real option %***	**All *Real option%***
Price revision	**1.20 (<0.01)**	**0.80 (<0.01)**
Price revision$^+$	**1.53 (<0.01)**	**1.72 (<0.01)**
Overhang (Retained/issued)	**0.01 (<0.01)**	**0.01 (<0.01)**
Size (ln proceeds)	-0.00 (0.87)	0.01 (0.46)
Pre-issue IPO returns	**0.07 (0.01)**	**0.05 (0.01)**
Pre-issue market returns	**0.65 (0.10)**	**0.85 (0.03)**
Technology ("Technology" = 1)	**0.19 (<0.01)**	---
Bubble (1999 or 2000 = 1)	**0.17 (<0.01)**	---
High revenue growth x *Real option%*	---	**All *Real option%* x High revenue growth**
High volatility x *Real option%*	---	**All *Real option%* x High volatility**
Technology x *Real option%*	---	**0.31 (<0.01)**
Bubble x *Real option%*	---	**0.32 (<0.01)**
Adjusted-R^2	46.9	52.5
Comparable adj-R^2 with one estimate of *Real option%*	45.0 (from Model 4; Table 3.6)	51.2 (from Model 5; Table 3.8)
N	790	790

6. Conclusion

In this paper, I argue that IPO underpricing is partially attributable to information asymmetry, in addition to strategic decisions made by issuers and underwriters. One reason strategic underpricing may occur is that underwriters trade off the benefits of higher fees (from higher issue proceeds) against the risk of holding large quantities of stock in a weak secondary market. Alternatively, underwriters may leave money on the table to ensure a continued information flow from investors about the market value of new issues. I argue that underpricing is not completely attributable to strategic 'incentive-based' underpricing. Information asymmetry theories imply a positive relationship between underpricing and the proportion of equity value comprised of embedded options. This implies that underpricing will persist, even if underwriters make genuine efforts to maximise offer proceeds.

I explicitly model the proportion of value comprised of embedded options - *Real option%* - by simulating revenue growth and profit margin over time. The analysis suggests that the value of embedded options is discounted by around 10 percent on average, in addition to any strategic underpricing. This is economically significant. For the mean IPO, it implies that $11 million of proceeds is left on the table (or $1 million in fees) due to information asymmetry. Reducing this asymmetry could therefore yield tangible benefits.

However, the increase in explanatory power is marginal, compared to what can be attributed to strategic decisions. The revision of offer price from the mid-point of the filing range remains the dominant predictor of underpricing and is the variable that is directly in control of the underwriter. In conclusion, there is evidence that information asymmetry remains one explanation for IPO underpricing, but is clearly dominated by underwriter or issuer incentives to underprice the stoc

Chapter 4

Research & development expenditure and the value of embedded options

1 Introduction

The analysis presented in Chapters 2 and 3 relies on equity valuations using *Discounted Cash Flow* and *Decision-tree* valuation models. I attribute the difference between these valuations to the value of embedded options and label this *Real option%* when computed as a percentage of total equity value. The economic rationale for this interpretation is that volatility of the revenue stream gives rise to growth and abandonment options, which management can exercise by altering reinvestment policy. In response to a high growth signal, management can respond by increasing investment and take the opposite action in a low growth state.

This management action is modelled through the assumption of a constant dividend payout ratio, which necessarily results in increased investment when earnings are high and decreased investment when earnings are low. However, perhaps what I compute as *Real option%* is measuring some other (unspecified) economic construct which is also associated with the volatility of revenue growth. If this is the case, I cannot necessarily interpret this variable as the proportion of value comprised of embedded options.

In this chapter, I provide corroborating evidence to support the argument that *Real option%* can be interpreted in this way. First, I show that *Real option%* is positively correlated with research and development (*R&D*) expenditure, which can be interpreted as the purchase of an option to proceed to commercialisation. Second, I replicate prior research which documents the association between returns and *R&D* expenditure (Lev and Sougiannis, 1996; Chan, Lakonishok and Sougiannis, 2001). I show that *Real option%* and *R&D*-intensity have comparable association with stock prices, returns and volatility. This is consistent with the market considering *Real option%* to have the same value-relevance as *R&D*-intensity.

This evidence provides support for the use of simulation models to value firms which make investments giving rise to embedded options. The implication for managers is that these techniques are useful for capital allocation. The implication for equity analysts and investors is that accuracy of their estimates of the value of *R&D*-intensive firms can be improved by incorporating the value of embedded options.

The chapter proceeds as follows. Section 2 presents empirical evidence on the association between *R&D* expenditure and equity value, returns and volatility; Section 3 presents the results; and Section 4 concludes the paper.

2 *R&D*-intensity and its association with value, returns and volatility

The accounting literature has documented a positive association between the capitalized value of *R&D* spending and the market value of equities and between R&D-intensity and the volatility of stock returns. But there is conflicting evidence of an association between *R&D*-intensity and subsequent stock returns. This paper addresses two research questions: (1) whether measures of *R&D*-intensity are positively correlated with the value of the firm's embedded options, as estimated by a simulation model; and (2) whether there is an association between *Real option%* and market value of equity, volatility of stock returns and the level of future returns. In this section, I summarise the relevant literature upon which this analysis is based.

The accounting literature has documented a positive association between the capitalized value of *R&D* spending and equity market value, implying that the market considers *R&D* expenses to be investments expected to yield positive future cash flows. Lev and Sougiannis (1996) find that equity prices are positively associated with the theoretical increase in book value of equity if *R&D* expenditures are capitalised rather than immediately expensed. This relationship is even stronger for very *R&D*-intensive firms. For firms with *R&D* expenditure in the upper quartile of sample firms, the ability to explain the variation in equity prices increases by 9 percent compared to the full sample. Using Australian data, Abrahams and Sidhu (1998) document a comparable association between market value and capitalised *R&D*. These results are consistent with the prior evidence of Sougiannis (1994).

There is also an association between *R&D*-intensity and the volatility of stock returns and earnings. Chan et al (2001) estimate a linear relationship between *R&D*/sales and the standard deviation of returns and report an average coefficient of 0.096. The average firm involved in *R&D* has an *R&D*/Sales ratio of 23 percent, implying that this activity increases the volatility of their returns by 2.2 percent. The volatility of future earnings is also positively associated with *R&D* spending as shown by Kothari, Laguerre and Leone (2002).

Support for these results is found in literature which measures the association between intangible assets, equity value and uncertainty. For software firms, the capitalised value of software development costs are positively associated with stock prices and the change in this value is associated with stock returns (Aboody and Lev, 1998). However, the authors also present evidence that the intensity of software capitalisation is positively associated with analysts' earnings forecast errors. In addition, there is evidence that of a negative association between the level of intangible assets and (1) the consensus in analysts' forecasts; and (2) the degree to which the mean forecast error is superior to individual forecasts, in terms of having less mean squared error (Barron, Byard, Kile and Riedl, 2002). These results suggest that firms a high level of intangible assets have greater uncertainty over their value. Seeing as these results were primarily due to the *R&D* expenditures of high-technology manufacturing firms, (such as electronics, drug and software companies) we can surmise that *R&D* expenditure is valuable, but its benefits are uncertain.

In contrast to the evidence on stock prices and volatility, there is conflicting evidence over whether *R&D* spending results in abnormal mean stock returns. Chan et al (2001) find that the average stock return on *R&D*-intensive firms is comparable to the average return for firms with no *R&D*. However, they do report an association between *R&D*-intensity and subsequent stock returns when they measure *R&D*-intensity as capitalised *R&D* relative to market value of equity. These firms are classed as *R&D*-intensive largely because their market value of equity has fallen significantly in the previous 12 months. Thus, *R&D* spending is only associated with subsequent abnormal returns for firms with prior negative returns who subsequently maintain their *R&D* spending.

Lev and Sougiannis (1996) also report an association between stock returns and capitalised *R&D* scaled by market value of equity. They state that this relationship was maintained even when they scaled by book value of assets or equity, but do not explicitly control for past share price performance. In sum, this research is consistent with an association between *R&D*-intensity and subsequent returns, but it is an unresolved question as to whether this is due to the economic benefits of *R&D* spending or simply reflects long-term stock price reversals.

As a whole this literature supports the notion that *R&D*-intensive firms have relatively volatile returns and earnings, but which earn average stock returns that are at least commensurate with risk. The model I put forward in Chapters 2 and 3 is that firms with high, volatile growth prospects have a greater proportion of their value consisting of embedded options. These firms are expected to be *R&D*-intensive firms. So consistent with the prior evidence, I test for a positive association between the option component of equity value (*Real option%*) and (1) *R&D*-intensity; (2) the market value of equity; (3) the volatility of stock returns; and (4) average stock returns.

3 Results

In this section, I present evidence that *Real option%* is positively associated with *R&D*-intensity. I also replicate research into the relationship between *R&D*-intensity and stock returns, values and volatility. This analysis shows that *Real option%* and *R&D*-intensity have a similar association with stock market values. As a whole, the evidence supports my view that *Real option%* can be interpreted as equity value attributable to embedded options.

The sample comprises the 44 percent of firm-years used in the Chapter 2 portfolio performance study which reported positive R&D expenditure. I consider only firms who report positive *R&D* expenditure. I do not attempt to analyse firms with zero *R&D* expenditure, because it is highly uncertain as to whether a zero value in the database actually represents zero expenditure or a missing value. In each part of the analysis there are minor restrictions imposed which reduces sample size. These restrictions are detailed in their respective sub-sections. Unless stated otherwise, the estimation techniques used are the same as those detailed in Chapter 2.

3.1 Association between the *Real option%* and *R&D*-intensity

In this section I present evidence that *R&D*-intensity is positively associated with *Real option%*. I measure *R&D*-intensity in a similar way to Chan et al (2001) and Lev and Sougiannis (1996). First, I compute *R&D* expenditure relative to Sales, Earnings, Dividends or Book Value of Equity. Second, I estimate the capitalised value of *R&D* expenditure, given prior evidence of an association between capitalised *R&D* and equity market values.

I measure the capitalised value of *R&D* expenditure for firm i in year t according to the equations below, which are modified versions of the equation used by Chan et al (2001) who rely on the empirical support of Lev and Sougiannis (1996). The first equation, the same as that used by Chan et al, implicitly assumes that the value of *R&D* expenditure is amortised over a five-year life and incorporates *R&D* expenditure that has been both amortised and capitalised. It is used when there is current *R&D* expenditure available, as well as a four-year history of *R&D* expenditure. The equation is:

$$Capitalised\ R\&D_{it} = R\&D\ Expenditure_{it} + 0.8\ R\&D\ Expenditure_{i,t-1} + 0.6\ R\&D\ Expenditure_{i,t-2} + 0.4\ R\&D\ Expenditure_{i,t-3} + 0.2\ R\&D\ Expenditure_{i,t-4} \quad (4.1)$$

For firms whose *R&D* expenditure for the past five years is unavailable, I modify the above equation be re-weighting the coefficients applicable to the available data history. This is to ensure that the estimate of capitalised *R&D* is not upwardly biased towards firms with a long reported history of *R&D* expenditure. That is, the adjustment is made to correct for a lack of *reported R&D* expenditure, primarily due to a short listing period, as opposed to the lack of *actual R&D* expenditure.

The above equation is consistent with *R&D* expenditure in year 0 being 25 percent more valuable than *R&D* expenditure last year, 67 percent more valuable than that incurred two years ago, and so on. I estimate capitalised *R&D* using the following equations, which maintain these relative weightings, and whose weights also sum to 3. The equations are:

$$\textit{Capitalised R\&D}_{it} \text{ (4-year history)} = 1.07\ \textit{R\&D Expenditure}_{it} + 0.86\ \textit{R\&D Expenditure}_{i,t-1} + 0.64\ \textit{R\&D Expenditure}_{i,t-2} + 0.43\ \textit{R\&D Expenditure}_{i,t-3} \quad (4.2a)$$

$$\textit{Capitalised R\&D}_{it} \text{ (3-year history)} = 1.25\ \textit{R\&D Expenditure}_{it} + 1.00\ \textit{R\&D Expenditure}_{i,t-1} + 0.75\ \textit{R\&D Expenditure}_{i,t-2} \quad (4.2b)$$

$$\textit{Capitalised R\&D}_{it} \text{ (2-year history)} = 1.67\ \textit{R\&D Expenditure}_{it} + 1.33\ \textit{R\&D Expenditure}_{i,t-1} \quad (4.2c)$$

$$\textit{Capitalised R\&D}_{it} \text{ (1-year history)} = 3.0\ \textit{R\&D Expenditure}_{it} \quad (4.2d)$$

I analyse the association between *R&D*-intensity and *Real option%* for the full sample, by cohort year and by IBES industries. I use more detailed industry classifications than those relied upon in the analysis of Chapters 2 and 3. In the earlier analysis, parameter estimates relating to volatility of revenue growth and margins were made on the basis of 11 IBES Industry Sectors over 18 years (198 Sector-year partitions). To make parameter estimates based on the more detailed industry grouping would materially decrease the size of those groups, and likely increase the standard error of those estimates.

In Panels A and B of Table 4.1, I compare the *R&D*-intensity of my sample to that used by Chan et al (2001). I report the aggregate *R&D*-intensity for the year and the IBES industry, and the aggregate *Real option%.* This minimises the impact of extreme values for denominators, which can be very low (in the case of Book value of equity) or very high (when sales are consolidated). Chan et al (2001) compute their figures in an identical manner.

The aggregate measures of *R&D*-intensity are 3.8 percent for *R&D*/Sales, 54 percent for *R&D*/Earnings, 10.3 percent for *R&D*/Book value of equity and 146 percent for *R&D*/Dividends. The aggregate value of capitalised *R&D* is 30 percent of book value of equity. These figures are comparable to those reported by Chan et al. For my sample, the mean *R&D*/Sales estimate is 3.7 percent in 1990 and 3.5 percent in 1995. These figures are close to the estimates of 3.4 and 3.8 percent recorded by Chan et al.

Table 4.1

Intensity of research and development activity and estimated value of embedded options

Panel A provides descriptive statistics for on R&D-intensity for 4155 who reported positive R&D expenditure during 1987-2004. The variables summarised are: R&D/Sales; R&D/Net profit (NPAT) where NPAT > 0; R&D/Book value of equity; R&D/Dividends; (5) Capitalised R&D/Book value of equity; and Real option% under the assumption that the competitive advantage period takes on values of 10, 20 or 30 years. Capitalised R&D is estimated according to equations 4.2a to 4.2d. Real option% is equal to 1 – *DCF* value/*Decision-tree* value. The valuation models underlying these valuations are summarised in Exhibits 2.2 and 2.9 of Chapter 2. Panel B presents the correlation coefficients amongst these variables. ***, ** and * refer to significance levels for two-tailed tests at the 1, 5 and 10 percent level, respectively.

Panel A: R&D-intensity by cohort year

		R&D **as a percent of:**				**Cap**	***Real option%*** **by CAP**		
Year	**N**	**Sales**	**NPAT**	**BV**	**Div**	**RD / BV**	**10**	**20**	**30**
1987	123	3.9	77	10.7	155	32	5	13	24
1988	117	3.7	64	10.0	147	17	9	18	28
1989	113	3.6	55	10.5	148	36	8	17	29
1990	129	3.7	61	12.0	148	42	6	13	22
1991	135	3.6	69	11.2	149	36	6	14	23
1992	143	3.6	86	10.9	139	35	6	11	20
1993	153	3.9	76	13.4	160	40	6	13	23
1994	157	3.8	65	12.5	145	39	5	12	21
1995	165	3.5	51	10.3	124	32	6	12	24
1996	167	3.6	45	10.4	130	31	6	15	27
1997	242	3.4	42	9.5	120	28	7	13	24
1998	262	4.2	49	11.8	151	32	7	16	29
1999	286	4.1	51	11.9	150	31	7	16	28
2000	319	3.8	46	10.4	143	29	10	19	32
2001	342	3.9	42	9.6	151	26	13	29	45
2002	394	4.2	60	10.0	166	27	17	35	52
2003	457	3.7	59	9.5	153	29	20	40	58
2004	451	3.5	51	8.2	143	24	19	39	57
Pooled	**4155**	**3.8**	**54**	**10.3**	**146**	**30**	**12**	**25**	**40**
Chan, Lakonishok and Sougiannis (2001)									
1985		3.0	84	8.1	146	21			
1990		3.4	79	9.6	149	26			
1995		3.8	65	10.9	165	29			

Panel B: R&D-intensity by IBES industry

		R&D **as a percent of:**				**Cap**	***Real option%*** **by CAP**		
IBES industry	**N**	**Sales**	**NPAT**	**BV**	**Div**	***R&D* / BV**	**10**	**20**	**30**
Building materials	150	27.7	145	18.7	5343	50	23	54	77
Svcs to medical profession	176	11.7	51	10.9	954	28	16	34	49
Office products	111	11.4	212	21.5	1814	53	14	32	49
Software & EDP services	226	11.0	87	12.6	1209	33	14	32	50
Electrical systems/devices	208	10.2	55	17.9	119	48	13	21	34
Electrical goods	153	9.7	185	10.5	3057	44	18	38	58
Precious metals	89	9.4	122	9.4	7518	25	17	38	56
Photo-Optical equip	115	7.5	125	15.2	1386	57	16	35	52
Leisure product	65	6.1	81	18.3	205	54	6	12	20
Containers	73	5.9	90	16.1	386	44	12	28	45
Undesignated energy	47	5.4	54	12.5	109	35	8	13	20
Electronics	110	4.5	80	12.5	176	41	8	17	28
Clothing	187	4.4	65	11.2	132	33	6	12	20
Auto part manufacturing	35	4.3	213	34.7	596	89	8	20	32
Building & related	20	3.1	45	7.1	141	44	8	16	27
Drugs	117	3.1	75	10.1	238	27	11	26	40
Nonferrous metals	450	3.0	47	8.6	232	33	26	53	72
Medical supplies	255	2.9	55	9.1	184	39	9	19	31
Hospital care	104	2.7	31	8.2	71	27	6	12	20
Savings & Loans	31	2.6	93	11.8	287	32	8	23	36
Pooled	**4155**	**3.8**	**54**	**10.3**	**146**	**30**	**12**	**25**	**40**
Chan, Lakonishok and Sougiannis (2001) – SIC Industries									
Computer prog, software & services		16.6	207	28	2833	55			
Drugs and pharmaceuticals		11.9	92	21	192	53			
Computers and office equipment		7.1	159	21	1242	56			
Measuring instruments		5.6	90	13	277	37			
Electrical equip excluding computers		4.9	58	10	242	26			
Communications		3.7	98	13	80	36			
Transportation equipment		3.6	126	17	298	46			

Table 4.1
Intensity of research and development activity and estimated value of embedded options (continued)

Panel C: Correlation between measures of R&D-intensity and Real option% (Pearson correlation coefficients reported in the bottom left; Spearman coefficients reported in the top right)

	R&D as a percent of...				Cap	*Real option%* by CAP		
	Sales	Earn-ings	Book value	Dividends	*R&D* / BV	10	20	30
R&D/Sales	---	88***	89***	79***	76***	40***	31**	33**
R&D/Earnings	63***	---	89***	90***	75***	44***	46***	47***
R&D/Book value	57***	83***	---	74***	84***	24	21	22
R&D/Dividends	70***	56***	28*	---	63***	62***	68***	69***
Cap *R&D*/Book value	46***	72***	84***	22	---	24	18	20
Real option% (CAP=10)	54***	34**	14	51***	11	---	89***	89***
Real option% (CAP=20)	56***	43***	19	57***	16	97***	---	99***
Real option% (CAP=30)	59***	46***	21	59***	19	95***	100***	---

Industry analysis provides evidence that *Real option%* is positively associated with *R&D*-intensity. In Panel B I present data on the 20 industries with the highest mean *R&D*/Sales ratios, and compare those estimates with data presented by Chan et al (2001). The industry analysis shows that *Real option%* is positively associated with *R&D*-intensity. For the 41 IBES industries with at least 20 observations, I measured the association between *R&D*-intensity and *Real option%* using Pearson and Spearman correlation coefficients. This represents 4000 of the 4155 observations in the *R&D* sub-sample (96 percent). These coefficients are presented in Panel C.

There is a significant positive association between *Real option%* and *R&D*/Sales, *R&D*/Earnings and *R&D*/Dividends, and about 30 percent of the variation in *Real option%* can be explained by *R&D*/Sales. Furthermore, of the 41 industries represented, six were jointly ranked in the top 10 by both *R&D*/Sales and *Real option%* and 13 were jointly ranked in the top 20. These numbers hold for *Real option%* estimated under all three assumptions for the competitive advantage period.

Thus, there is evidence that *R&D*-intensive firms have higher estimated values for *Real option%*, which is largely a function of the volatility of revenue growth. It is likely that a major proportion of *R&D* expenditure is incurred to create options to proceed to commercialisation. However, the value of these investments is unlikely to be incorporated in near-term earnings forecasts or analysts' forecast cash flows into perpetuity. Therefore, a *DCF* valuation based on those forecasts understates the value of embedded options. In contrast, a *Decision-tree* valuation can incorporate the value of optimal exercise and the difference between the *DCF* and *Decision-tree* valuations can be attributed to the value of embedded options. The association between *Real option%* and *R&D*-intensity provides support for this hypothesis. In the remainder of this chapter I examine whether *Real option%* and *R&D*-intensity have the same association with returns volatility, market values and average returns.

3.2 Association between volatility of stock returns and *Real option%*

Chan et al (2001) provide evidence that *R&D*-intensity is associated with stock returns. They estimate the coefficients of the following model, using ordinary least squares regression, for each year from 1975-1995:

$$\sigma_{it} = \gamma_{0t} + \gamma_{1t} LNSIZE + \gamma_{2t} LNAGE + \gamma_{3t} RDS_{it} + \sum_{j=1}^{L} \phi_{jt} IND_{ijt} + \varepsilon_{it} \qquad (4.3)$$

where:

σ_{it} = the standard deviation of monthly stock returns over the 12 months following the measurement of *R&D*;
$LNSIZE_{it}$ = the natural logarithm of market capitalisation;
$LNAGE_{it}$ = the natural logarithm of the firm's age;
RDS_{it} = research and development expenditure relative to sales;
IND_{it} = indicator variables for industries based on 2-digit SIC codes (or 3-digit codes in the case of selected technology industries); and
the subscripts *i* and *t* refer to firm *i* and year *t*.

Chan et al (2001) report an average coefficient on RDS of 0.096 and state that the average *R&D*/Sales for firms reporting any *R&D* is 23 percent. This is consistent with the average *R&D*-intensive firm having volatility of stock returns 2.2 percent higher than a firm with no *R&D*.

I repeat this analysis using my data set and a number of measures of *R&D*-intensity. I exclude the age variable as this data is not available. I also use 40 IBES industry classifications for the indicator variables and present the results both including and excluding these variables. I then conduct the same analysis using *Real option%* instead of *R&D*-intensity. The regression results are summarised in Table 4.2.

The results show that both *R&D*-intensity and *Real option%* are positively associated the volatility of stock returns and that *Real option%* has greater explanatory power. These results hold even after including indicator variables for the 41 IBES industries. In that case, the coefficient on *Real option%* assuming CAP=30 is 0.102. This implies that for every 10 percent of value which is comprised of embedded options, the monthly volatility of its stock returns increases by about 1 percent (an increase in annualised volatility of 3.5 percent). This result is consistent with the modelling of Schwartz and Moon (2000) who predict a positive association between the volatility of revenue growth and stock price volatility.

Table 4.2
Explaining the volatility of returns

Table 4.2 presents the results of seven ordinary least squares regressions of the volatility of returns on several explanatory variables. The volatility of returns is computed each year as the standard deviation of 12 monthly returns. These returns are the continuously-compounded returns on the stock, assuming reinvestment of dividends. All regression models include the natural logarithm of market capitalisation as an explanatory variable. Regressions in Panel B include 40 indicator variables for IBES industries where the number of firm-years in the sample is at least 20. The variable of interest in the seven models are: (1) *R&D*/Sales; (2) *R&D*/Earnings, where earnings > 0, (3) *R&D*/Book value of equity; (4) Capitalised *R&D*/Book value of equity, where capitalised *R&D* is estimated using equations 2a-2d; and (5-7) *Real option%* is estimated under the assumption that the competitive advantage period is 10, 20 or 30 years, respectively. The coefficients presented are the average coefficients from 18 regressions run on annual data starting at 30 April each year from 1987-2004. Significance levels for the coefficients are estimated using t-statistics computed from the standard error of these 18 coefficient estimates. The adjusted-R^2 presented is the mean estimate of the 18 individual adjusted R^2 estimates. There are 3680 firm-years for which all data is available, which represents an average sample size in each regression of 204. The minimum number of observations in any given year is 111 and the maximum is 359. *p*-values for two-tailed tests of significance are presented in brackets.

Panel A: Regressions excluding indictor variables for IBES industries

	Coefficients (*p*-values)						
Variable of interest	*R&D* as a percent of...			Cap *R&D*/BV	*Real option%* by CAP		
	Sales	Earnings	Book value		10	20	30
Intercept	0.158	0.162	0.168	0.170	0.150	0.136	0.120
	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)
In Mktcap	-0.009	-0.009	-0.009	-0.009	-0.008	-0.007	-0.006
	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)
Variable of interest	0.223	0.007	0.046	0.003	0.169	0.101	0.092
	(<0.01)	(<0.01)	(<0.01)	(0.02)	(<0.01)	(<0.01)	(<0.01)
Adjusted-R^2 (%)	26.5	18.8	17.8	16.1	18.1	20.5	23.4

Panel B: Regressions including indictor variables for IBES industries

	Coefficients (*p*-values)						
	R&D as a percent of...			Cap *R&D*/BV	*Real option%* by CAP		
	Sales	Earnings	Book value		10	20	30
Intercept	0.163	0.164	0.168	0.169	0.139	0.130	0.119
	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)
In Mktcap	-0.009	-0.009	-0.009	-0.009	-0.008	-0.007	-0.006
	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)
Variable of interest	0.176	0.004	0.029	0.003	0.295	0.128	0.102
	(<0.01)	(<0.01)	(<0.01)	(0.03)	(<0.01)	(<0.01)	(<0.01)
Adjusted-R^2	31.8	28.6	27.4	27.2	30.4	31.9	33.4

Panel C: Mean estimates of descriptive statistics for each of 18 regressions

	Mean	Median	Standard deviation
Volatility of monthly returns (%)	10	9	5
R&D/Sales (%)	8	3	27
R&D/Earnings (%)	97	45	265
R&D/Book value (%)	14	8	47
Capitalised *R&D*/Book value (%)	97	25	867
Real option%			
CAP = 10 years	10	9	5
CAP = 20 years	21	20	11
CAP = 30 years	32	32	15

3.3 Association between market values and *Real option%*

There is evidence that *R&D* expenditure is positively associated with the market value of equity. Lev and Sougiannis (1996) estimated the value of capitalised *R&D* as a weighted sum of *R&D* expenditures, and report the following mean result from 16 ordinary least squares regressions on annual data from 1976-1991.

$$P = 9.025 + 5.193X^{E} + 0.96\left(X^{C} - X^{E}\right) + 2.37\left(BV^{C} - BV^{E}\right) \qquad (4.4)$$

where:

P = share price;
X^E = reported earnings per share;
X^C = estimated earnings per share assuming *R&D* expenditure is capitalised;
BV^E = reported book value of equity per share; and
BV^C = estimated book value per share assuming *R&D* expenditure is capitalised.

The mean coefficients on reported earnings (X^E) and the capitalisation increase to book value ($BV^C - BV^E$) are statistically significant. The mean and standard error of the coefficient on ($BV^C - BV^E$) are consistent with every dollar of capitalised *R&D* having a market value of about \$2.00 - \$2.60. Lev and Sougiannis (1996) estimated the capitalised value of *R&D* assuming an amortisation rate which approximates 20 percent a year, a rate which is relied upon by Chan et al (2001). In Australia, the prescribed accounting treatment of *R&D* expenditure allows management more discretion to account for this as capital expenditure. This allowed Abrahams and Sidhu (1998) to perform a comparable analysis on a sample of firms who capitalise *R&D*. From a pooled regression on 114 firm-years they report the following result. All coefficients are significantly different from zero.

$$MVE = 0.368 + 1.401TALRD - 1.749TL + 2.478RD \qquad (4.5)$$

where:

MVE = market value of equity per share;
$TALRD$ = total assets, less balance sheet research and development, per share;
TL = total liabilities per share; and
RD = balance sheet research and development per share.

As with Lev and Sougiannis, the mean estimate of the market value of capitalised *R&D* is over \$2.00 for every dollar of capitalised *R&D*. But the higher standard error of this estimate implies that every dollar of capitalised *R&D* has a market value of around \$0.50 - \$4.50. In the spirit of this prior research, I estimate share price as a linear function of book value of equity and two measures of *R&D*-intensity – capitalised *R&D* per share and *R&D* expenditure per share. I then repeat the analysis after replacing the dependent variable with an estimate of the option component of equity value, expressed on a dollars per share basis. Thus, I estimate the coefficients to the following regressions models, the results of which are presented in Table 4.3.

$$Price = \alpha + \beta_1 BVPS + \beta_2 Capitalised\ R\&D\ or\ R\&D\ expenditure\ per\ share \quad (4.6a);\ and$$

$$Price = \alpha + \beta_1 BVPS + \beta_2 Per\ share\ value\ of\ embedded\ options \quad (4.6b)$$

where:

Capitalised R&D is estimated via equations 2a-2d; and

Value of embedded options = the difference between equity values estimated under the *DCF* and *Decision-tree* valuation methods, assuming competitive advantage periods of 10, 20 and 30 years.

Table 4.3
Market value of equity and value of embedded options

Table 4.3 presents the results of six ordinary least squares regressions of share price on several explanatory variables. All regressions models include the book value of equity per share as an explanatory variable. The variable of interest in the remaining five models is (1) capitalised *R&D* per share; (2) *R&D* expenditure per share; and (3-5) estimated dollar value of embedded options, as estimated under the assumption that the competitive advantage period is 10, 20 or 30 years. The coefficients presented are the average coefficients from 18 regressions run on annual data starting at 30 April each year from 1987-2004. Significance levels for the coefficients are estimated using t-statistics computed from the standard error of these 18 coefficient estimates. The adjusted-R^2 presented is the mean estimate of the 18 individual adjusted R^2 estimates. There are 3908 firm-years for which all data is available, which represents an average sample size in each regression of 214. The minimum number of observations in any given year is 105 and the maximum is 430. *p*-values for two-tailed tests of significance are presented in brackets.

Panel A: Regression results

Variable of interest	**n/a**	**Cap *R&D*/per share**	***R&D*/per share**	**Dollar value of embedded options per share by CAP**		
				10	**20**	**30**
Intercept	10.39	10.10	9.60	9.95	10.13	10.16
	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)
BVPS	1.29	1.27	1.20	1.16	1.24	1.26
	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)
Variable of interest	---	0.23	2.17	1.05	0.13	0.05
		(0.03)	(<0.01)	(0.00)	(0.07)	(0.11)
Adjusted-R^2 (%)	47.5	48.9	49.8	48.9	48.3	48.2

Panel B: Mean estimates of descriptive statistics for each of 18 regressions

	Mean	Median	Standard deviation
Share price	19.87	16.69	14.29
Book value per share	7.40	5.25	7.05
Capitalised *R&D* per share	2.77	1.15	5.80
R&D per share	0.67	0.33	1.07
Dollar value of embedded options:			
CAP = 10 years	1.14	0.68	1.50
CAP = 20 years	3.31	1.85	4.47
CAP = 30 years	7.39	3.91	10.61

The coefficients and adjusted-R^2 presented in Table 4.3 are the mean estimates from 18 regressions run on annual data from 1987-2004. Consistent with prior research, there is a positive association between capitalised *R&D* expenditure and share price. But the mean coefficient of 0.23 is significantly lower than the estimated values of around 2.50 reported by Lev and Sougiannis (1996) and Abrahams and Sidhu (1998). This coefficient estimate has a standard error or 0.10, implying that one dollar of capitalised *R&D* has a market value of just $0.06 – 0.40 per share, based on a 90 percent confidence interval. The coefficient on *R&D*/sales of 2.17 and its standard error of 0.48 are consistent with every dollar of annual *R&D* expenditure increasing market value by about $1.21 – 3.01 per share.

These estimated coefficients can be interpreted in the following way. For the 18 years of data on which the regression analysis is performed, the mean estimate of capitalised *R&D* per share is $2.77. According to the estimated regression coefficient, this has a market value of just $0.64 per share. The mean estimate of *R&D* expenditure per share is $0.67, which has an estimated market value of $1.45.

Now consider the coefficients on the per share dollar of embedded options. These coefficients decrease from 1.05 to 0.05 as the assumed competitive advantage period increases from 10 to 30 years. But the mean estimate of embedded options per share increases with an increase in *CAP*, from $1.14 to $7.39 per share. If the mean estimated market value of embedded options is comparable for all five measures (two measures of *R&D*-intensity and three estimates of embedded option value) this provides further evidence that they capture the same construct. I performed this comparison by taking the mean estimate of each measure of embedded options from the 18 regression samples, and estimated a 90 percent confidence interval for its market value. The results of this comparison are:

- The theoretical value of capitalised *R&D* is $2.77 per share, which has an estimated market value of $0.18 – 1.12.
- The annual *R&D* expenditure is $0.67, which has an estimated market value of $0.89 – 2.02.
- If CAP is assumed to be 10 years, the theoretical value of embedded options is $1.14 per share, which has an estimated market value of $0.78 – 1.61.
- If CAP is assumed to be 20 years, the theoretical value of embedded options is $3.31 per share, which has a market value of $0.04 – 0.83.
- If CAP is assumed to be 30 years, the theoretical value of embedded options is $7.39 per share, which has a market value of $-0.01 – 0.74.

Under CAP assumptions of 20 or 30 years, the estimated market value of embedded options has upper bounds of $0.83 and $0.74, which are less then the lower bound of the confidence interval drawn from the *R&D* expenditure proxy. However, the confidence interval drawn from the CAP assumption of 10 years is very comparable to that drawn from *R&D* expenditure. In addition, the confidence intervals estimated under CAP assumptions of 20 and 30 years are comparable to those drawn from the capitalised *R&D* analysis. Thus, the evidence provides broad support for the contention that theoretical value of embedded options has the same market value as investments in *R&D*.

3.4 Association between stock returns and *Real option%*

In Section 2, I highlighted the limited evidence of an association between *R&D*-intensity and subsequent stock returns. Recall that Chan et al (2001) were only able to find evidence of a positive association between *R&D*-intensity and stock returns for firms whose recent share market returns were poor, and thus had high ratios of *R&D*/market value. They also note the association between *R&D*-intensity and volatility of returns, so any remaining outperformance may simply be due to risk.

Whether we should expect *R&D*-intensive stocks to earn above-average returns is unclear. As shown in Section 3.2, there is an association between *R&D*-intensity and the volatility of returns. If this additional volatility is driven by a risk factor that is priced by the equity market, we should expect these stocks to earn higher average returns. However, *R&D*-intensive stocks can also be characterised as glamour stocks, given their relatively low book-to-market equity ratios and high earnings growth. Given that glamour stocks typically earn lower returns than value stocks, we could observe *R&D*-intensive stocks earning low average returns.

In this section I present the results of a comparison of the returns to portfolios formed on the basis of *R&D* relative to sales, and *Real option%*. For each of the 18 years from 1987-2004, I formed two sets of quintile portfolios after ranking stocks on *R&D*/Sales, and *Real option%*, assuming a competitive advantage period of 10, 20 or 30 years. I then analysed the characteristics of these portfolios and their subsequent returns performance. The results of this analysis are presented in Table 4.4, which can be directly compared to the results of Chan et al (2001).

The results presented in Table 4.4 confirm that portfolios formed on the basis of *Real option%* have comparable performance to those formed on the basis of *R&D*-intensity. Stocks ranked in the top quintile by *R&D*-intensity had average annual returns of 12.9 percent, which was

2.6 percent higher than those in the bottom quintile. For stocks ranked according to *Real option%*, there was a comparable difference in performance of 2.4 percent. However, these differences in returns were not statistically significant. In addition, the higher volatility of returns in top quintile portfolios meant that their Sharpe ratios were slightly lower than those in the bottom quintile. I computed the Sharpe ratio as the annual return minus the risk-free rate, relative to the annualised standard deviation of the 12 monthly returns.

However, there is one important difference between the portfolios formed on the basis of *R&D*-intensity and *Real option%*. The data confirms that *R&D*-intensive stocks can be considered glamour stocks. As *R&D*-intensity increases there is a systematic decline in the book-to-market equity ratio, the earnings-to-price ratio and the dividend yield. However, for portfolios formed on the basis of *Real option%*, this trend is not apparent. In fact, firms in the top quintile based on *Real option%* have a significantly higher average book-to-market equity ratio than firms in the bottom quintile (0.45 versus 0.33; p-value <0.01). This is likely to occur because *Real option%* is driven primarily by the volatility of revenue growth, with the level of revenue growth having less importance. Thus, firms with low, volatile revenue growth will have a higher *Real option%* than those firms with high, stable revenue growth.

However, this data remains consistent with *Real option%* being a valid estimate of its intended construct – the proportion of equity value comprised of embedded options. This is because the book-to-market equity ratio has a greater association with past revenue growth than future revenue growth, as demonstrated by Chan, Karceski and Lakonishok (2003). They showed a systematic relationship between the book-to-market equity ratio and realised growth over the previous five years. However, they failed to find an association between the book-to-market equity ratio and growth over the subsequent five years. If the book-to-market equity ratio is largely a function of historical growth, the data presented in Table 4.4 is consistent with the following summation:

- *R&D*-intensive firms can be considered glamour stocks, characterised by low book-to-market equity ratios, earnings-to-price ratios and dividend yield. But these financial ratios do not necessarily mean that a higher proportion of equity value is comprised of embedded options. These financial ratios may simply reflect the market's expectation that expected growth will be high, not necessarily that the volatility of growth will be high.
- In contrast, firms with high estimated *Real option%* have a high volatility of expected revenue growth and this association will be stronger the lower the level of current growth. This evidence remains consistent with the interpretation of *Real option%* as the proportion of equity value comprising embedded options.

Table 4.4

Returns and characteristics of portfolios classified by *R&D* relative to sales or by *Real option%*

At the end of April each year from 1987 to 2004, all stocks are ranked by their *R&D* expenditure relative to sales or by *Real option%* and assigned to one of five equally-sized portfolios. *Real option%* is estimated according to the procedure detailed in Chapters 2 and 3, and assumes a competitive advantage period of 30 years. The sample is drawn from stocks which had reported *R&D* expenditure, were part of the S&P500 and the NASDAQ Composite Index as at 30 April 2005, and for which IBES consensus EPS forecasts were available for at least two forecast years. The table reports mean estimates for the following variables: (1) the annual stock return, assuming continuous compounding; (2) the Sharpe ratio, estimated as the annual stock return minus the yield on 10-year Government bonds, divided by the annualised standard deviation of monthly stock returns; (3) *R&D* divided by sales; (4) *R&D* divided by market value of equity; (5) book value of equity divided by market value of equity; (6) sales divided by the market value of equity; (7) earnings-to-price, computed as last year's earnings per share, divided by share price; (8) dividend yield, computed as last year's dividend relative to share price; (9) return on equity, computed as the last annual earnings divided by book value of equity; and (10) the natural logarithm of market capitalisation. The annual returns reported in the Chan et al (2001) panel assume discrete period compounding.

	Quintiles				
	1 (Low)	2	3	4	5 (High)
Quintiles formed according to *R&D*/Sales					
Annual return (%)	10.34	10.97	9.05	10.37	12.93
Sharpe ratio	0.41	0.50	0.33	0.37	0.40
R&D/Sales (%)	0.61	1.93	3.92	7.34	30.14
R&D/Market value of equity (%)	0.84	2.46	5.04	6.48	8.05
Book-to-market equity	0.54	0.43	0.41	0.39	0.33
Sales-to-market equity	1.68	1.40	1.40	1.00	0.51
Earnings-to-price (%)	6.79	6.45	6.80	5.95	4.31
Dividend yield (%)	2.77	2.33	2.27	2.06	1.51
Return on equity (%)	17.51	25.28	17.97	7.59	2.72
Natural logarithm of market capitalisation	7.89	7.81	7.98	7.80	7.61
Quintiles formed according to *Real option%* (CAP = 30 years)					
Annual return (%)	9.63	10.05	11.23	10.74	12.00
Sharpe ratio	0.38	0.39	0.51	0.37	0.34
R&D/Sales (%)	4.08	3.53	4.89	8.68	22.72
R&D/Market value of equity (%)	2.43	3.47	4.17	6.51	6.26
Book-to-market equity	0.33	0.42	0.48	0.43	0.45
Sales-to-market equity	0.79	1.32	1.37	1.39	1.15
Earnings-to-price	5.68	6.75	6.33	6.15	5.55
Dividend yield (%)	2.79	2.23	1.87	1.73	2.18
Return on equity (%)	28.65	21.66	14.77	15.10	-9.42
Natural logarithm of market capitalisation	8.92	8.09	7.71	7.46	6.89
Quintiles formed according to *R&D*/Sales (Chan, Lakonishok and Sougiannis, 2001)					
Annual return (%)	19.11	20.68	21.14	21.67	18.15
R&D/Sales (%)	0.46	1.36	2.89	5.71	22.62
R&D/Market value of equity (%)	1.30	3.21	5.69	8.07	10.88
Book-to-market equity	0.90	0.85	0.80	0.70	0.54
Sales-to-market equity	3.18	2.59	2.30	1.71	1.03
Earnings-to-price (%)	8.00	7.59	6.84	5.37	0.58
Dividend yield (%)	2.58	2.43	2.08	1.53	0.57
Return on equity (%)	10.88	10.99	10.69	9.83	1.83
Natural logarithm of market capitalisation	4.69	4.65	4.60	4.54	4.23

4 Conclusion

In this paper, I provide corroborating evidence that *Real option%* is a measure of the proportion of equity value comprised of embedded options. First, I show that *Real option%* is positively correlated with *R&D*-intensity and that around 30 percent of the variation in *Real option%* can be explained by *R&D*-intensity. Second, I show that *Real option%* and *R&D*-intensity have comparable association with the volatility of stock returns. Third, I estimate the market value of embedded options on a per share basis. When the market value of embedded options is estimated using capitalised *R&D*, the confidence interval around this value is comparable to that implied by *Real option%* under an assumed competitive advantage period of 20 or 30 years. When this confidence interval is estimated using *R&D*/Sales, it is comparable to that implied by *Real option%* under an assumed competitive advantage period of 10 years. Finally, quintile portfolios formed on the basis of *Real option%* had comparable investment performance to those formed on the basis of *R&D*-intensity. Sharpe ratios for the top and bottom quintiles formed on *Real option%* were 0.40 and 0.41. For portfolios formed on the basis of *R&D*/Sales, Sharpe ratios were 0.34 and 0.38 for the top and bottom quintiles.

In conclusion, this analysis provides support for *Real option%* as a valid economic construct – the proportion of equity value comprised of embedded options.

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