

Momentum, Acceleration and Non-Linearities in
Equity Valuation
on the Shanghai Stock Exchange

By

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Statement of Original Authorship

I hereby declare that this submission is my own work and to the best of my knowledge it contains no materials previously published or written by another person, or substantial proportions of materials which have been accepted for the award of any other degree or diploma at Victoria University of Wellington or any other educational institutions, except where due acknowledgement is made in this dissertation. Any contribution made to the research by others, with whom I have worked at Victoria University of Wellington or elsewhere, is explicitly acknowledged in this dissertation.

I also declare that the intellectual content of this dissertation is the product of my own work, except to the extent that assistance from others in the project's design and conception or in style, presentation and linguistic expression is acknowledged.

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ABSTRACT

The standard empirical paradigm for assessing the relationship between the market value of a firm's equity and the accounting information appearing in the firm's financial statements, is based on the assumption that the firm is indefinitely constrained to operate within its existing investment opportunity set. Based on this assumption, the Ohlson (1995) model, which is developed by characterising a firm's investment opportunity set in terms of a first order vector system of stochastic differential equations, shows that the market value of a firm's equity will be a linear combination of its current abnormal earnings, the current value of an "information" variable and the current book value of its equity. However, the pre-existing empirical evidence shows that the Ohlson (1995) model does not provide a satisfactory description of the relationship between the market value of a firm's equity and the information appearing in its published financial statements.

Recent developments in equity valuation theory also show that the higher order derivatives of the accounting variables comprising a firm's investment opportunity set - that is, the momentum and acceleration of the accounting information disclosed in a firm's financial statements - can potentially make a significant contribution to the overall market value of equity. This in turn will mean that a firm's investment opportunity set ought to be characterised in terms of a second or third order system of stochastic differential equations. Omitting the momentum and acceleration of the accounting variables from the equity valuation process could lead to the under-estimation of equity values. Moreover, recent empirical evidence also shows that the market value of a firm's equity is potentially, a complex non-linear function of a firm's accounting information appearing in financial statements. The non-linear effects arise out of the adaptation (real) options associated with a firm's ability to modify or even abandon its existing investment opportunity set.

However, empirical work on the relationship between the market value of equity and the accounting information appearing in financial statements continues to be

based on linear models which do not take account of either the momentum and acceleration in a firm's accounting variables or the non-linear effects associated with the real options available to the firm. Given this, it is all but inevitable that when these valuation effects are ignored, systematic biases will arise in empirical work dealing with the determinants of equity values. Moreover, empirical work in this area has been almost exclusively based on North American and European data. There is, in particular, a dearth of empirical work in developing countries like the People's Republic of China.

This dissertation refines the equity valuation models summarised in the literature by incorporating momentum, acceleration and non-linear equity valuation effects and then empirically tests them against data obtained from the Shanghai Stock Exchange (SSE). The empirical analysis summarised in this dissertation shows that neither earnings momentum nor earnings acceleration exhibit a significant impact on the market value of equity for the pooled sample data on which the empirical analysis is based. However, when the pooled sample data are divided into three equally numerous groups based on each firm's operational efficiency, earnings momentum for firms with moderate operational efficiency exhibits a significant association with the market value of equity. This contrasts with the low-efficiency and high-efficiency sub-sample firms, where earnings momentum appears to have an imperceptible effect on equity prices. However, whilst it is shown that earnings momentum can have an impact on equity prices of moderate-efficiency firms, its effect is minimal in explanatory terms and adds very little to parsimonious regression models based on earnings and book value alone. Earnings acceleration does not appear to impact on equity values - neither for the pooled sample data nor for any of the three efficiency sub-samples.

The empirical analysis summarised in this dissertation also shows that there is a strong non-linear relationship between the market value of equity and the accounting information appearing in published financial reports for firms listed on the SSE. In particular, for low-efficiency firms liquidation option value appears to make a significant contribution to the overall market value of equity. For high-efficiency firms growth option value appears to make a significant contribution to

the overall market value of equity. For firms with moderate operational efficiency real option value is negligible and thus for these firms the relationship between the market value of equity and the accounting variables on which the empirical analysis is based is approximately linear.

List of Tables

Table 4.1 Distributional Properties of Full-sample Data 1999-2012.....	121
Table 4.2 Coefficient Estimates for First Order Model (M1), Second Order Model(M2) and Third Order Model (M3) for the Full-sample Data 1999-2012	124
Table 4.3 Multi-collinearity Diagnostics (Full-sample)	126
Table 4.4 Distributional Properties of Low-efficiency, Steady-state and High-efficiency Sub-samples 1999-2012	128
Table 4.5 Coefficient Estimates for First Order Model (M1), Second Order Model(M2) and Third Order Model (M3) for Low-efficiency, Steady-state and High-efficiency Sub-samples 1999-2012	134
Table 4.6 Multi-collinearity Diagnostics (Low-efficiency Sub-sample)	137
Table 4.7 Multi-collinearity Diagnostics (Steady-state Sub-sample)	137
Table 4.8 Multi-collinearity Diagnostics (High-efficiency Sub-sample)	137
Table 4.9 Distributional Properties of Full-sample Data 2005-2012.....	142
Table 4.10 Coefficient Estimates for First Order Model (M1), Second Order Model(M2) and Third Order Model (M3) for the Full-sample Data 2005-2012	145
Table 4.11 Multi-collinearity Diagnostics (Full-sample)	147
Table 4.12 Distributional Properties of Low-efficiency, Steady-state and High-efficiency Sub-samples 2005-2012	149
Table 4.13 Coefficient Estimates for First Order Model (M1), Second Order Model(M2) and Third Order Model (M3) for Low-efficiency, Steady-state and High-efficiency Sub-samples 2005-2012	156
Table 4.14 Multi-collinearity Diagnostics (Low-efficiency Sub-sample)	158
Table 4.15 Multi-collinearity Diagnostics (Steady-state Sub-sample)	158
Table 4.16 Multi-collinearity Diagnostics (High-efficiency Sub-sample)	158
Table 5.1 Distribution Properties of Full-sample Data.....	172
Table 5.2 Coefficient Estimates for Linear Model (M1), Reduced High Order Approximation Model (M2) for the Full-sample Data	175
Table 5.3 Multi-collinearity Diagnostics for M2 Regression Model (Full-sample)	178
Table 5.4 Distributional Properties of Low-efficiency, Steady-state and High-efficiency Sub-samples.....	182
Table 5.5 Industrial Distribution for Low-efficiency, Steady-state and High-efficiency Sub-samples.....	184
Table 5.6 Coefficients Estimate for Liner Model (M1) and Reduced High Order Approximation Model (M2) for Low-efficiency, Steady-state and High-efficiency Sub-samples	191

Table 5.7 Multi-collinearity Diagnostics (Low-efficiency Sub-sample)	193
Table 5.8 Multi-collinearity Diagnostics (Steady-state Sub-sample)	193
Table 5.9 Multi-collinearity Diagnostics (High-efficiency Sub-sample)	193
Table 5.10 Total Variance Explained (Full-sample)	203
Table 5.11 Component Matrix (Full-sample)	204
Table 5.12 Coefficients Estimate for Components Regressions for Full-sample, Low-efficiency, Steady-state and High-efficiency Sub-samples	205
Table 5.13 Total Variance Explained (Low-efficiency Sub-sample)	209
Table 5.14 Component Matrix (Low-efficiency Sub-sample)	210
Table 5.15 Total Variance Explained (Steady-state Sub-sample)	213
Table 5.16 Component Matrix (Steady-state Sub-sample)	214
Table 5.17 Total Variance Explained (High-efficiency Sub-sample)	217
Table 5.18 Component Matrix(High-efficiency Sub-sample)	218

Table of Contents

Chapter 1 Introduction	1
1.1 Introduction	1
1.2 Objectives and Motives of the Thesis.....	2
1.3 Research Methodology and Data.....	4
1.4 Structure of the Thesis	5
Chapter 2 Literature Review	11
2.1 Introduction	11
2.2 Equity Valuation with Uncertain Cash Flows	13
2.3 Residual Income Valuation Model (RIV Model)	17
2.4 Ohlson's Linear Information Dynamics	20
2.5 Empirical Implications of the Ohlson (1995) Model.....	33
2.6 Other Empirical Work in the Area.....	49
2.7 Conclusion.....	66
Chapter 3 Real (Adaptation) Option Valuation, Momentum and Acceleration	69
3.1 Introduction	69
3.2 Traditional Valuation Models and Option-style Models	70
3.3 Meaning and Existence of Real Option	71
3.4 Real Option Theory and Valuation Models	75
3.4.1 Ashton, Cooke and Tippet (2003) Model	75
3.4.2 Zhang (2000) Model.....	83
3.4.3 Yee (2000) Model.....	95
3.4.4 Conclusion.....	98
3.5 Momentum, Acceleration and the Valuation of Equity	99
3.6 Conclusion.....	106
Chapter 4 Methodology and Empirical Analysis on Earnings Momentum and Earnings Acceleration	109
4.1 Introduction	109
4.2 Equity Valuation Model Incorporating Earnings Momentum and Acceleration	111
4.3 Sample Data, Descriptive Statistics and Empirical Results.....	115
4.3.1 Complete Data (from 1999 to 2012).....	115
4.3.2 Complete Data (from 2005 to 2012).....	138
4.4 Conclusion.....	159
Chapter 5 Methodology and Empirical Analysis on Non-linearities	163
5.1 Introduction	163
5.2 Equity Valuation Model Incorporating Real Option Value	165
5.3 Descriptive Statistics and Empirical Results	169

5.3.1 Descriptive Statistics and Empirical Results on Pooled Data.....	169
5.3.2 Descriptive Statistics and Empirical Results on Efficiency Groups	179
5.4 Low Explanatory Power for the Low-efficiency Group of Firms	194
5.5 Principal Component Analysis	199
5.5.1 PCA on Pooled Data.....	200
5.5.2 PCA on Low-efficiency Sub-sample Data.....	207
5.5.3 PCA on Steady-state Efficiency Sub-sample Data	211
5.5.4 PCA on High-efficiency Sub-sample Data.....	215
5.6 Conclusion.....	219
Appendix	2190
Chapter 6 Conclusion.....	233
6.1 Summary and Main Findings	233
6.2 Contribution, Limitations of the Study and Future Research	238
6.2.1 Contribution.....	238
6.2.2 Limitation of Methodology and Theoretical Modelling	239
6.2.3 Future Research	242
Bibliography	244

Chapter 1

Introduction

1.1 Introduction

The standard empirical paradigm for assessing the relationship between the market value of a firm's equity and its determining variables is based on the assumption that firms are indefinitely constrained by their existing investment opportunity sets. This in turn will mean that there will have to be a purely linear relationship between equity prices and their determining variables. However, recent and emerging empirical evidence is compatible with the hypothesis that the market value of a firm's equity is potentially, a complex non-linear function of a variety of determining variables, including a firm's earnings, the book values appearing on its balance sheet and perhaps, other contextual and economic variables as well (Burgstahler & Dichev, 1997; Ashton et al., 2003; Di-Gregorio (2006) etc.). Despite this, empirical work on the relationship between the market value of equity and its determining variables continues to be based on linear models that neglect the non-linear effects associated with a firm's ability to modify or even abandon its existing investment opportunity set. Given this, it is all but inevitable that when these non-linear valuation effects are ignored, systematic biases will arise in empirical work based on the linear valuation models which have traditionally characterised this area of the literature. Moreover, despite the gradually expanding volume of empirical literature which investigates the non-linear relationship between market value of a firm's equity and its determining variables for firms listed on the North American and European stock markets and the gradually emerging empirical evidence pertaining to developing countries, there is a dearth of empirical work dealing with non-linearities in equity valuation in developing countries like the People's Republic of China.

In the twenty years to 2011 the real growth rate in Gross Domestic Product (GDP) for the Chinese economy was 10.48% (per annum). This compares with a real growth rate in GDP for the U.S. and British economies of 2.61% and 2.27%

respectively over the same period. Hence, by any measure the Chinese economy continues to grow at a remarkable rate. Chinese capital and financial markets have also become increasingly more sophisticated as the Chinese economy has grown. The Shanghai Stock Exchange (SSE), for example, was established in 1990 as part of the Chinese government's agenda to move from a totally planned economy towards a mixed economy. Since its inception the SSE has experienced rapid development in terms of the number of companies listed on its trading boards, trading volumes and overall market capitalisation. Furthermore, China's admission to the World Trade Organisation (WTO) in 2001 means that Chinese capital markets are gradually being opened up to foreign capital investment. On 1 December, 2002 the Chinese government promulgated the Qualified Foreign Investment Institution Law (QFII) which is the enabling legislation for foreign institutional investors to purchase Yuan-denominated equity stocks. This was not allowed before the passage into law of these regulations. Given that foreign direct investment is now permitted in China, it necessarily follows that the analytical and empirical work summarised in this dissertation will have important implications from the standpoint of efficient resource allocation. Equity valuation models are widely used to identify the fundamental (or intrinsic) values of equity stocks and investors use these fundamental values in the investment decisions they have to make. If investment decisions are based on inappropriate valuation models then this can lead to a serious misallocation of resources and a lowering of living standards for the Chinese economy as a whole. Thus it is an interesting and important question to analysts, investors, government policy makers and researchers alike as to which valuation models should be applied in order to make optimal investment decisions.

1.2 Objectives and Motives of the Thesis

The principal aim of this dissertation is to assess and evaluate the non-linear relationships which exist between the market value of equity and accounting information for firms listed on the SSE. A secondary objective is to empirically examine whether earnings momentum and earnings acceleration have any impact

on the market value of equity for firms listed on the SSE.¹ Thus, this study seeks to address the following questions:

1. Do earnings momentum and earnings acceleration have an impact on the market value of equity for firms listed on the SSE? Moreover, does the impact that earnings momentum and earnings acceleration have on the market value of equity vary according to the level of the firm's operational efficiency?
2. Is there a non-linear relationship between the market value of equity and the accounting information summarised in published financial statements for firms listed on the SSE? Moreover, do the non-linear effects, if any, vary according to the level of the firm's operational efficiency?

This study of equity valuation for firms listed on the SSE is important for a number of reasons. First, although numerous studies have examined the association between earnings momentum and price momentum this study is the first to provide empirical evidence based on a properly articulated theoretical model of earnings momentum and earnings acceleration and the impact they have on the market value of equity itself rather than on the price momentum of equity stocks; in particular, for firms listed on the SSE. Second, estimates of the impact of accounting information on the market value of equity can be biased if non-linear effects are ignored. Although compelling emerging empirical evidence shows that a highly non-linear relationship exists between equity value and the accounting information summarised in a firm's financial statements, all previous empirical studies which test the non-linearity hypothesis are based on piece-wise linear approximations of the relationship between the market value of equity and its corresponding accounting information. This study is amongst the first to examine the non-linearities which arise in equity valuation using a properly articulated theoretical model. It is also amongst the first to provide evidence that the non-linear terms -

¹ Momentum is defined as the first difference in a variable. Thus, if $x(t)$ is a firm's earnings for the year ending at time t , then the momentum in earnings is defined as $x(t) - x(t - 1)$. In the accounting context momentum is really just a measure of persistence. The acceleration in earnings is just the second difference in the earnings variable; namely, $x(t) - 2x(t - 1) + x(t - 2)$.

which proxy for real option values - contribute significantly to the overall market value of a firm's equity.² The empirical analysis summarised in the later sections of the dissertation also emphasises the importance of non-linear terms in explaining stock prices for firms with different operational efficiencies.

In summary, the main aim of this dissertation is to shed light on the role of non-linearities in equity valuation. The dissertation shows strong theoretical and empirical support for the hypothesis that there is a non-linear relationship between the market value of a firm's equity and its determining variables - although for a narrow class of firms where real option value is negligible, the relationship between the market value of equity and its determining variables can be reasonably approximated in terms of a linear function. The empirical analysis summarised in the dissertation also shows that for firms with moderate operational efficiency, earnings momentum can have an impact on the overall market value of equity.

1.3 Research Methodology and Data

The empirical analysis summarised in this study is basically comprised of two parts. In the first part, it is noted how Davidson and Tippett (2012, pp. 286-298) have generalised the Ohlson (1995) and Ashton et al. (2003) equity valuation models so that a firm's investment opportunity set can be stated in terms of a higher (that is, second or third) order system of stochastic differential equations. This in turn will mean that under the Davidson and Tippett (2012) model, the momentum and acceleration of the variables comprising the firm's investment opportunity set have the potential to make a significant contribution to the overall market value of the firm's equity. This contrasts with the Ohlson (1995) and Ashton et al. (2003) equity valuation models which assume that the firm's investment opportunity set can be stated in terms of a first order vector system of stochastic differential equations and therefore, takes no account of the momentum and acceleration of the variables comprising the firm's investment opportunity set. Since the Ohlson (1995) model is widely regarded as a benchmark model by capital market

² Another possible explanation for the observed non-linear relationship which exists between the summary measures that appear in a firm's financial statements and the market value of its equity arises from the conservative accounting that characterises accounting practices (Basu, 1997).

researchers the first part of the empirical analysis summarised in my dissertation assesses whether earnings momentum and/or earnings acceleration have any impact on equity values. Here, the empirical analysis summarised in the dissertation is based on a large sample of equity stocks listed on the SSE covering the period from 1999 to 2012.

The dissertation emphasises that a number of models have shown that there will have to be a non-linear relationship between the market value of a firm's equity and its determining variables due to the fact that firms will invariably have the capacity to modify or even completely abandon their investment opportunity sets (Zhang, 2000; Yee, 2000; Ashton et al., 2003). Given this, the second part of the empirical analysis summarised in the dissertation assesses the form and magnitude of the non-linear relationships which exist between the market value of equity and the information appearing in published financial reports. The empirical analysis summarised in this section of the dissertation highlights the important contribution which real option value can make in explaining the overall market value of equity for firms listed on the SSE.

1.4 Structure of the Thesis

This dissertation consists of six chapters. The main ideas of each chapter are summarised as follows:

Chapter 2: Literature Review

This chapter provides a summary of the more important equity valuation models to be found in the literature. The chapter commences with a consideration of the traditional Discounted Cash Flow valuation model and then moves on to consider the Discounted Dividend model. It then demonstrates another equivalent way to determine the value of a firm's equity, a way that relates a firm's value to the information appearing in its published financial reports - the Residual Income Valuation (RIV) model. Further, it shows, based on the RIV model, how Ohlson (1995) formulates the relationship between a firm's abnormal earnings, the

information variable³ and the book value of its equity in terms of a first order vector system of stochastic differential equations. More often than not this vector system of stochastic differential equations is described as the Ohlson (1995) “linear information dynamics” or alternatively, the firm’s “investment opportunity set”. The Ohlson (1995) model shows that the market value of a firm’s equity will be a linear combination of its current abnormal earnings, the current value of the information variable and the current book value of its equity. This chapter then goes on to summarise the literature dealing with the empirical implications of the Ohlson (1995) linear information dynamics. The summary provided of the literature in this area shows that it is unlikely that the Ohlson (1995) linear information dynamics can provide a realistic description of the way that firms’ abnormal earnings, book values and the information variable evolve through time. This in turn will mean that the relationship between the market value of a firm’s equity and the determining variables comprising the linear information dynamics cannot take the purely linear form implied by the Ohlson (1995) equity valuation model (Dechow et al., 1999; Myers, 1999; Morel, 2003). The concluding sections of this chapter summarise empirical evidence which shows that there is a convex and highly non-linear relationship between equity values and the determining variables comprising the Ohlson (1995) linear information dynamics.

Chapter 3: Real (Adaptation) Option, Momentum and Acceleration

This chapter introduces a theoretical framework for determining the impact that the real options available to firms and the momentum and acceleration of the variables comprising a firm’s investment opportunity set will have on the market value of a firm’s equity. Its main brief is to summarise how real option value has been included as an element of equity value in the models of Zhang (2000), Yee (2000) and Ashton et al. (2003) which are the principal models published in this area of the literature. The common feature shared by all these models is that they show how the market value of a firm’s equity is comprised of two complementary

³ The information variable is unique to the Ohlson (1995) model and captures all information relevant to the value of a firm’s equity that has not as yet been incorporated into the firm’s accounting records.

valuation components. The first of these is determined by discounting the stream of expected future cash flows the firm is expected to earn under the assumption that it will apply its existing investment opportunity set indefinitely into the future. The second element of equity value arises out of the options the firm has to change or modify its existing investment opportunity set. This chapter also shows how the momentum and acceleration of the variables comprising a firm's investment opportunity set and stochastic variations in the real option value arising out of a firm's ability to change or modify its investment opportunity set, impact on the overall market value of the firm's equity.

Chapter 4: Methodology and Empirical Analysis on Earnings Momentum and Earnings Acceleration

This chapter is the first of two chapters that summarise the empirical results relating to the various equity valuation models outlined in previous chapters. In particular, this chapter constitutes part of the main empirical results of this dissertation and assesses whether earnings momentum and earnings acceleration have any impact on the market value of equity for firms listed on the SSE. To the best of the author's knowledge no previous study has investigated and measured the impact of earnings momentum and earnings acceleration on the market value of a firm's equity itself rather than on the price momentum of its equity stock. Nonetheless, recent developments in equity valuation theory (Davidson & Tippet, 2012) show that the momentum and acceleration of variables comprising the firm's investment opportunity set can have a potentially significant impact on the market value of its equity. Given this, the purpose of this chapter is to examine the relationship between earnings momentum and earnings acceleration and the market value of equity. The empirical work summarised in this chapter shows that earnings momentum can have an impact on the market value of equity for a narrow class of firms with moderate operational efficiency. There is, however, no evidence that earnings acceleration has any impact on the market value of equity for firms listed on the SSE.

Chapter 5: Methodology and Empirical Analysis on Non-linearities

This chapter is the second of the two chapters that summarise the empirical results relating to the equity valuation models considered in earlier chapters. Its principal brief is to assess the form and magnitude of the non-linear relationships which exist between the market value of equity and the information appearing in the published financial reports of firms listed on the SSE. It highlights the importance of real option value in explaining the market value of equity for both pooled sample firms and sample firms with different operational efficiencies. As in Chapter 4, the data in this chapter consists of a large sample of firms listed on the SSE covering the period from 1999 until 2012. The chapter commences by noting how firms invariably possess strategic and operational (real) options that provide them with the potential to modify or even abandon their existing investment opportunity sets. Moreover, these real options have the potential to make a significant contribution to the overall market value of equity. This in turn will mean that there will have to be a non-linear relationship between the market value of a firm's equity and its determining variables. The empirical analysis summarised in this chapter shows that there is, in fact, a strong non-linear relationship between the market value of equity for firms listed on the SSE and the information appearing in their published financial reports. In particular, when the pooled sample data are partitioned into low operational efficiency, moderate (that is, steady-state)⁴ operational efficiency and high operational efficiency sub-sample data, they return empirical results which are compatible with the real option hypothesis and evidence of a highly non-linear relationship between the market value of equity and the accounting (that is, determining) variables employed in the empirical analysis. For low-efficiency firms the liquidation option value makes a significant contribution to the overall market value of equity. For high-efficiency firms growth option value makes a significant contribution to the overall market value of equity. For firms with moderate operational efficiency real option value is negligible and thus the relationship between the market value of equity and the accounting (that is,

⁴ In subsequent sections of this dissertation I will use the terms "moderate efficiency" and "steady-state efficiency" interchangeably.

determining) variables on which the empirical analysis is based is approximately linear - consistent with the Ohlson (1995) model.

Chapter 6: Conclusion

This last chapter of the dissertation summarises the main ideas, findings and contributions of this dissertation. My dissertation contributes to the accounting-based capital markets literature in three significant aspects. Its first contribution stems from the fact that it provides the first empirical evidence on the impact that earnings momentum and earnings acceleration can have on the market value of equity; in particular, for firms listed on the SSE. Here, my empirical analysis is compatible with the hypothesis that earnings momentum does have an impact on the equity values of firms with moderate operational efficiency. This in turn implies that the investment opportunity sets of such firms must be defined in terms of a higher order system of stochastic differential equations.

A second contribution of my dissertation is that it contributes to our understanding of the application of real option analysis in equity valuation by summarising the strengths and weaknesses of the three most prominent non-linear equity valuation models in the extant literature; namely, the Ashton et al. (2003), Zhang (2000) and Yee (2000) equity valuation models.

Third, although compelling empirical evidence now shows that a convex and highly non-linear relationship appears to exist between equity prices and the summary measures which appear in corporate financial statements, all previous empirical studies which test the non-linearity hypothesis are based on piece-wise linear approximations of the relationship between the market value of equity and its determining variables. This contrasts with the empirical analysis summarised in this dissertation for firms listed on the SSE which is based on a power series expansion of the Ashton et al. (2003) non-linear equity valuation model as developed by Davidson and Tippett (2012). The empirical analysis based on the Davidson and Tippett (2012) power series expansion shows that whilst there is a complementary relationship between the valuation coefficients associated with a

firm's earnings and the book value of its equity, it also highlights the very significant impact which the real options generally available to firms can have on the overall market value of a firm's equity.

Chapter 2

Literature Review

2.1 Introduction

There is now a large volume of papers that express the value of a firm's equity in terms of its past cash flows and profitability as well as the profits and cash flows that it is expected to earn in the future (Koller et al., 2005; Christensen & Feltham, 2009; Henschke, 2009). In particular, the role of accounting (and other) information in the equity valuation process has been of fundamental interest to analysts, investors and researchers etc. Analysts use the information summarised in a firm's financial statements in conjunction with more general macroeconomic information (e.g. the expected rate of growth in GDP, the expected rate of inflation, the political stability of the country in which the firm operates, etc.) to make estimates of the operating cash flows a firm will earn in the future. These cash flows are then discounted back to their present values using an estimate of the cost of capital for the particular firm and/or industry in which the firm operates. The underlying principle is that investors should not pay more for an equity security than the present value of the future operating cash flows it is expected to earn. In other words, the investment decision must be based on a comparison between the intrinsic value of an equity security and its current market price (Reilly & Brown, 2003).

Discounted Cash Flow valuation models recognise that equity value must be related to the return investors expect to receive from holding it. Taking account of the required rate of return, which reflects the risk of the investment (that is, the cost of capital for the given equity security), the present value of the equity security is determined by discounting the stream of its expected future cash flows. This is the fundamental principle of valuation developed by John Burr Williams (1938), one of the founding fathers of what today is known as the "fundamental analysis approach to equity valuation". Here, we need to recall, however, that the equity holders in a firm will be the eventual recipients of all the operating cash flows

earned by the firm. This in turn will mean that the present value of the dividends paid out over the life of the firm must be equal to the present value of the operating cash flows the firm will earn. This shows that one can determine equity value either by discounting the future dividends a firm is expected to pay or alternatively, by discounting the future operating cash flows it is expected to earn. This is because the present value of its future dividends must adjust to (that is, be equal to) the present value of its operating cash flows (Miller & Modigliani, 1961).

As previously noted, a distinguishing feature of modern equity valuation theory is that it acknowledges how fundamental equity values must be determined within the context of uncertain future cash flows. Given this, in the next section we demonstrate how the seminal analysis of Rubinstein (1976) may be used to determine the fundamental (or intrinsic) value of an equity security under conditions of uncertainty. Moreover, Kay (1976) and Peasnell (1982), amongst others, have shown that when “clean surplus” accounting is practised, the present value of a firm’s expected future operating cash flows must be equal to the current book value of the firm’s equity plus the present value of its expected future residual income stream.⁵ A firm’s residual income is equal to its accounting (that is, its book) profit over a given period less its cost of capital multiplied by the book value of its equity at the beginning of that period. In proving this result, Kay (1976) and Peasnell (1982) open up a direct link between the intrinsic (or fundamental) value of a firm’s equity and the information appearing in the firm’s financial statements. Hence, in section 2.3 of this chapter we provide a formal development of the residual income model and of its implications for the valuation of a firm’s equity. In section 2.4 we follow Ohlson (1995) in showing how the evolution of the numbers appearing in a firm’s financial statements as well as other industry and macroeconomic data can be developed in terms of a first order vector system of stochastic differential equations. The solution of this system of differential equations will include, amongst other things, the firm’s future expected residual income (or earnings) and we demonstrate how Ohlson (1995) uses these figures in

⁵ The clean surplus identity requires that all profits and losses incurred by the firm appear on its profit and loss account and that increments in the book value of the firm’s equity are comprised of the profit (or loss) appearing on the firm’s profit and loss account less any provisions that have been made for the payment of dividends.

conjunction with the residual income valuation model articulated in section 2.3 to estimate the intrinsic (or fundamental) value of the firm's equity. In section 2.5 we summarise the empirical evidence relating to the Ohlson (1995) equity valuation model. This shows that the Ohlson (1995) model generally returns intrinsic values which are more than 20% below the actual market values of the equity securities on which the empirical analysis is based. In section 2.6, we briefly summarise the other important empirical papers in this area. This empirical work demonstrates that there is a potentially convex relationship between the market value of a firm's equity and the summary information appearing in the firm's financial statements. This in turn will mean that the numerous methodologies appearing in the literature that are based on the assumption that there is a pure linear relationship between equity values, the information appearing in a firm's financial statements and other industry and macroeconomic data are fundamentally flawed. Our argument will be that the models in this area of the literature need to be modified so as to take account of the convex relationships that exist because of the real options firms possess to modify or even completely abandon the investment opportunity sets on which their current productive activities are based. Section 2.7 presents our summary conclusions for this chapter.

2.2 Equity Valuation with Uncertain Cash Flows

Suppose one lets $D(t)$ denote the dividends paid by an equity security at time t . It then follows that the fundamental (or intrinsic) value of the equity security can be determined from the following equation (Ohlson, 1983):

$$P(0) = \sum_{t=1}^{\infty} R_f^{-t} D(t) \quad (2.1)$$

where $P(0)$ is the price of the equity security at time zero and R_f is one plus the risk free rate of interest. Here it will be recalled that the classical models in this area are based on the assumption of certain (or perfectly anticipated) cash flows and that the risk free rate of interest will be the appropriate discount rate because of this. One can generalise the above model, however, so that it does in fact account

for uncertain cash flows by invoking the analysis of Rubinstein (1976). Thus, suppose one lets $s(t)$ denote the “state of the world” at time t . The state of the world is determined in accordance with the circumstances and events that influence the evolution of a firm’s future cash flows; for example, drought as against rain, or an economy that is in boom as against an economy that is in depression, etc. Moreover, let $D[s(t)]$ denote the dividend which the firm will pay should state $s(t)$ eventuate at time t . Thus, a firm may pay a dividend of \$1 per share in one year’s time if the economy is in a state of boom, whereas it will omit the payment of dividends if the economy is in a state of depression. Let $Z[s(t)]$ be the current price (at time $t=0$) of a dividend that promises to pay a unit of consumption if state $s(t) = 1, 2, 3, \dots, M$ is realised at time $t > 0$. Then the market value of a security that pays a dividend of $D[s(t)]$ should state $s(t)$ eventuate at time $t = 1, 2, 3, \dots, N$ will be:

$$P(0) = \sum_{t=1}^{\infty} \sum_{s(t)=1}^M Z[s(t)]D[s(t)] \quad (2.2)$$

A simple example of the application of the above valuation formula is provided by a firm that pays a dividend of $D[s(t)] = \$1$ irrespective of which of the M states occur at time t . It then follows that at each of the N time points the shareholders of

the firm will receive \$1 with certainty. This in turn will mean that $\sum_{s(t)=1}^M Z[s(t)] = \frac{1}{R_f}$

where, as previously, R_f is one plus the risk free rate of interest. Moreover, let

$\pi[s(t)]$ be the probability assessed at time $t=0$ that state $s(t)$ will occur at

time $t > 0$. One can then define the random variable $Z'[s(t)] = \frac{Z[s(t)]}{\pi[s(t)]}$ in which case

it follows that the price (or the market value) of the security as given by equation (2.2) can be re-stated as:

$$P(0) = \sum_{t=1}^{\infty} \sum_{s(t)=1}^M Z'[s(t)]D[s(t)]\pi[s(t)] = \sum_{t=1}^{\infty} E_0\{Z'[s(t)]D[s(t)]\} \quad (2.3)$$

where $E_0(\cdot)$ is the expectations operator taken at time zero. Next, define the random variable $Y[s(t)] = E_0\{Y(t)\}Z'[s(t)]R_f^t$ in which case it follows $Z'[s(t)] = \frac{Y[s(t)]}{E_0\{Y(t)\}R_f^t}$. Substitution into equation (2.3) will then show that the market value of equity, $P(0)$, at time zero will be:

$$P(0) = \sum_{t=1}^{\infty} \frac{E_0\{Y[s(t)]D[s(t)]\}}{E_0\{Y(t)\}R_f^t} \quad (2.4)$$

Here, however, it will be recalled that the covariance between $Y[s(t)]$ and $D[s(t)]$ is given by:

$$\text{Cov}_0\{Y[s(t)];D[s(t)]\} = \sum_{t=1}^{\infty} E_0\{Y[s(t)]D[s(t)]\} - E_0\{Y[s(t)]\}E_0\{D[s(t)]\}$$

This in turn enables one to re-write the above result as:

$$P(0) = \sum_{t=1}^{\infty} \frac{E_0\{D[s(t)]\} + \frac{\text{Cov}_0\{Y[s(t)];D[s(t)]\}}{E_0\{Y(t)\}}}{R_f^t} \quad (2.5)$$

Since the denominator in the above valuation equation is the risk free rate of interest, R_f^t , it necessarily follows that the present value of a security equals the sum of the present values of the expected future dividends to be paid, discounted at the riskless rate of interest as adjusted by the risk of the dividend patterns at the different future dates. This adjustment procedure will in turn depend on the exogenous characteristics of the economy. Moreover, Rubinstein (1974, p. 411) shows that the random variable $Y[s(t)]$ will be the marginal utility of a representative agent's consumption in a standard neo-classical model of inter-temporal consumption choice. Moreover, one can also let the number of states increase without limit in which case dividend payments accrue in continuous time.

It then follows that the present value of the future stream of dividend payments will be:

$$P(0) = \int_0^{\infty} e^{-rt} E_0[D(t)] \langle 1 + \text{Cov}_0 \left\{ \frac{Y(t)}{E_0[Y(t)]}, \frac{D(t)}{E_0[D(t)]} \right\} \rangle dt \quad (2.6)$$

where $r = \log(R_f)$ is the continuously compounded risk free rate of return and where we have dropped the reference to the state space, $s(t)$, for convenience.

Moreover $\text{Cov}_0 \left\{ \frac{Y(t)}{E_0[Y(t)]}, \frac{D(t)}{E_0[D(t)]} \right\}$ is the covariance of the “normalised” marginal utility of consumption, $\frac{Y(t)}{E_0[Y(t)]}$, with the “normalised” dividend payment, $\frac{D(t)}{E_0[D(t)]}$.

If one assumes that the covariance between the normalised marginal utility of consumption and the normalised dividend payment takes the following form:

$$\text{Cov}_0 \left\{ \frac{Y(t)}{E_0[Y(t)]}, \frac{D(t)}{E_0[D(t)]} \right\} = - (1 - e^{-\gamma t}) \quad (2.7)$$

where $\gamma > 0$ is a parameter, then this implies that in absolute terms the covariance between the normalised marginal utility of consumption and the normalised dividend payment will grow with time. Here one should note that the variance (or standard deviation) associated with both the dividend payments and the marginal utility of consumption of the representative economic agent will increase the further one looks into the future. The correlation between these variables, however, will more than likely be reasonably stable no matter how far one looks into the future. Since the correlation coefficient is the covariance divided by the product of the standard deviations of the marginal utility of consumption and the dividend payment, it follows that one would expect the covariance between these two variables to increase in absolute terms the further one looks into the future. Moreover, Rubinstein (1974, p. 412) shows that under a mild set of regularity

conditions the correlation between the normalised marginal utility of consumption and the normalised dividend payment will have to be negative, reflecting the fact that “securities tend to be more valuable if they tend to have high dividends in dates and states with relatively low per capita consumption.” Both of these attributes are captured by our formulation for the covariance between the normalised marginal utility of consumption and the normalised dividend payment as summarised above in equation (2.7).

One can substitute equation (2.7) into equation (2.6) and thereby show that the present value of the future stream of dividend payments will be:

$$P(0) = \int_0^{\infty} e^{-rt} E_0[D(t)] [1 - (1 - e^{-\gamma t})] dt = \int_0^{\infty} e^{-it} E_0[D(t)] dt \quad (2.8)$$

where $i = (r + \gamma)$ is the discount rate. Note that the discount rate is comprised of the continuously compounded risk free rate of interest, r , plus a premium for risk as captured by the parameter γ . Moreover, the above formulation generalises the classical Discounted Dividend model of Williams (1937), Gordon (1962) and others so that it encompasses uncertainty in the future dividends (and by implication, operating cash flows) to be paid by the given firm.

2.3 Residual Income Valuation Model (RIV Model)

Our analysis in previous sections shows that one can determine the intrinsic (or fundamental) value of an equity security by computing the present value of the future dividends it is expected to pay or, equivalently, the present value of its expected future operating cash flows. There is, however, a third way in which the value of a firm's equity can be determined - one that leads to the same value for equity as discounting its expected future dividends or discounting the stream of the operating cash flows it is expected to earn (Miller & Modigliani, 1966). One can illustrate this technique by first defining $b(t)$ to be the book value of the firm's equity at time t as recorded in its financial statements. Moreover, let $x(t)$ be the firm's accounting or book profits on an annualised basis which accrue to equity

over the instantaneous period from time t until time $(t + dt)$. Finally, assume that all profits and losses are governed by the “clean surplus identity”. This requires that all profits and losses incurred by the firm appear on its profit and loss account and that increments in the book value of the firm’s equity are comprised of the profit (or loss) appearing on the firm’s profit and loss account less any provisions that have been made for the payment of dividends. This will mean that the relationship between the book value of the firm’s equity, the profits (or losses) it earns and the dividends it pays will be as follows:

$$db(t) = (x(t) - D(t))dt \quad (2.9)$$

Here $db(t) = b(t + dt) - b(t)$ is the increment in the book value of the firm’s equity over the instantaneous time period from time t until time $t + dt$ and, as previously, $D(t)$ is the dividend payment it makes on an annualised basis made over this same period of time. Note in particular how the clean surplus identity implies that dividend payments can be re-stated in terms of the accounting profit and changes in the book value of equity, or $D(t)dt = x(t)dt - db(t)$. In turn, this will mean that the expected present value of the future dividend payments can be expressed as:

$$P(0) = \int_0^{\infty} e^{-it} E_0[D(t)]dt = E_0\left[\int_0^{\infty} e^{-it}(x(t)dt - db(t))\right] \quad (2.10)$$

where i is the discount rate which, as previously noted, is comprised of the continuously compounded risk free rate of interest, r , plus a premium for risk, γ . Now, one can apply integration by parts to the component of the above integral involving the book value of equity; namely:

$$\int_0^{\infty} e^{-it} db(t) = [e^{-it}b(t)]_0^{\infty} + i \int_0^{\infty} e^{-it}b(t)dt$$

Evaluating the first term on the right hand of this expression shows:

$$[e^{-it}b(t)]_0^{\infty} = \lim_{t \rightarrow \infty} \{e^{-it}b(t)\} - b(0)$$

Hence, if one is to progress beyond this point then one must ensure that the expected book value of equity remains finite as the period over which the present value of the future expected dividend payments is computed becomes infinitely large. This is known as a “transversality requirement” and ensures that the market value of the firm’s equity will always remain finite (Becker, 2008). In the present context the transversality requirement takes the form:

$$\lim_{t \rightarrow \infty} \{e^{-it} E_0[b(t)]\} = 0$$

One can then evaluate the integral defining the present value of the expected future dividend payments as follows:

$$P(0) = E_0 \left[\int_0^{\infty} e^{-it} (x(t)dt - db(t)) \right] = E_0 \left[\int_0^{\infty} e^{-it} x(t)dt - i \int_0^{\infty} e^{-it} b(t)dt \right] + b(0)$$

Thus, if one defines $a(t) = x(t) - ib(t)$ as the firm’s residual income or abnormal earnings it then follows that the present value of the stream of expected future dividend payments can be restated as:

$$P(0) = b(0) + \int_0^{\infty} e^{-it} E_0[a(t)]dt \quad (2.11a)$$

Or in discrete form as:

$$P(0) = b(0) + \sum_{t=1}^{\infty} \frac{E_0[a(t)]}{(1+i)^t} \quad (2.11b)$$

One should note also how the abnormal earnings, $a(t)$, is comprised of the accounting profit, $x(t)$, attributable to equity less a capital charge, $ib(t)$, based on the book value of the firm’s equity. This in turn will mean that if the firm records all its assets and liabilities at their market value then one would expect its abnormal earnings to fluctuate around a mean of zero. However, the historical cost conventions on which accounting practices have generally been based will mean

that balance sheets seldom fully reflect the market values of the resources available to firms; that is, firms tend to practice “conservative” accounting (Billings & Morton, 2001; Cotter & Donnelly, 2006). This will mean that residual income will typically assume positive values even when firms are earning only “normal” returns on the resources available to them (Richardson & Tinaikar, 2004; Gode & Ohlson, 2006). The important point to be made here, however, is that the above result shows that the book value of the firm’s equity, plus the present value of its future expected abnormal earnings, must be equal to the present value of the expected future dividend payments the firm will make. Moreover, since the present value of the expected future dividend payments must be equal to the present value of the firm’s expected operating cash flows (Miller & Modigliani, 1961), we also have the important result that the book value of the firm’s equity plus the present value of its future expected abnormal earnings must be equal to the present value of the firm’s expected future operating cash flows.

2.4 Ohlson’s Linear Information Dynamics

If one is to develop the abnormal earnings model formulated in the previous section into a fully articulated equity valuation model then one must be able to document how a firm’s abnormal earnings will evolve through time. It is here that the equity valuation model developed by Ohlson (1995), and others, is seen as a major breakthrough because of the way it links accounting information to equity values (Bernard, 1995). The Ohlson (1995) model assumes that the increment in a firm’s abnormal earnings, $da(t) = a(t + dt) - a(t)$, over the instantaneous period from time t until time $(t + dt)$ depends on the current level of its abnormal earnings, $a(t)$, as well as an information variable, $v(t)$, which captures all the information relevant to the value of a firm’s equity that has not as yet been incorporated into the firm’s accounting records. As such, $v(t)$ captures information that will affect future abnormal earnings and book values and includes things such as new patents, regulatory approval of new drugs for pharmaceutical companies, new long-lived contracts and order backlogs which have not as yet been fully reflected in the firm’s accounting records (Myers, 1999). Thus, in the Ohlson (1995) model the combination of current earnings, current book value and the information variable

act as “sufficient statistics” for the firm’s expected future abnormal earnings. The expected future abnormal earnings can then be used in conjunction with equation (2.11a) to determine the expected present value of the firm’s future operating cash flows.

Ohlson (1995) formulates the relationship between a firm’s abnormal earnings, the information variable and the book value of its equity in terms of a first order vector system of stochastic difference equations. This allows one to capture the important interdependencies which exist between the factors that most directly influence the value of a firm’s equity. It is for this reason that the first order vector system of stochastic difference equations describing the evolution of these variables is often referred to as the firm’s investment opportunity set. Here we need to note, however, that most large firms have so many transactions in any given period that it is reasonable to assume that the variables comprising the firm’s investment opportunity set effectively evolve in continuous time (Cox & Miller, 1965, p. 146; Bergstrom, 1990, p. 1). This will mean that the first order vector system of stochastic difference equations on which the original Ohlson (1995) model is based may be reduced to an investment opportunity set which evolves in terms of the following vector system of first order stochastic differential equations (Ashton et al., 2003):

$$\begin{pmatrix} \frac{da(t)}{dt} \\ \frac{dv(t)}{dt} \end{pmatrix} = \begin{pmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{pmatrix} \begin{pmatrix} a(t) \\ v(t) \end{pmatrix} + \begin{pmatrix} k_1 & 0 \\ 0 & k_2 \end{pmatrix} \begin{pmatrix} \frac{dz_1(t)}{dt} \\ \frac{dz_2(t)}{dt} \end{pmatrix} \quad (2.12)$$

or, in matrix notation:

$$\tilde{u}'(t) = Q\tilde{u}(t) + Kz'(t)$$

Here $\tilde{u}(t) = \begin{pmatrix} a(t) \\ v(t) \end{pmatrix}$ is the vector whose elements are the instantaneous abnormal earnings, $a(t)$, attributable to equity and the information variable, $v(t)$, that captures

information relevant to the value of the firm's equity but which has not, as yet, been incorporated into the firm's accounting records. Moreover:

$$u'(t) = \begin{pmatrix} \frac{da(t)}{dt} \\ \frac{dv(t)}{dt} \end{pmatrix}$$

is the vector whose elements are the derivatives of the variables comprising the firm's investment opportunity set. Next, is the matrix:

$$Q = \begin{pmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{pmatrix}$$

whose elements, c_{11} , c_{12} , c_{21} and c_{22} , are the structural coefficients associated with the firm's investment opportunity set. The structural coefficients capture the sensitivity of increments in the variables comprising the firm's investment opportunity set to the existing levels of these variables. Moreover, K is a matrix whose diagonal elements are a set of "normalising" constants:

$$k_1 = \frac{(i - c_{11})(i - c_{22}) - c_{21}c_{12}}{(i - c_{22})} \text{ and } k_2 = \frac{(i - c_{11})(i - c_{22}) - c_{21}c_{12}}{c_{12}}$$

and whose off-diagonal terms are all zero. These normalising constants simplify the algebra associated with manipulating the firm's investment opportunity set but otherwise have no substantive role to play in the valuation of the firm's equity. Finally:

$$\frac{dz_1(t)}{dt} \text{ and } \frac{dz_2(t)}{dt}$$

are uncorrelated white noise processes with variance parameters of σ_1^2 and σ_2^2 respectively.

There are several points about the articulation of the firm's investment opportunity set given here that require further amplification explanation. First amongst these is

that simple algebraic manipulation shows how the firm's abnormal earnings evolve in terms of the following process:

$$\frac{da(t)}{dt} = -c_{11}\left(\frac{-c_{12}}{c_{11}}v(t) - a(t)\right) + k_1\frac{dz_1(t)}{dt} \quad (2.13)$$

This means, that apart from a stochastic component, the firm's abnormal earnings will gravitate towards a long-run mean of $\frac{-c_{12}}{c_{11}}v(t)$. Moreover, the force with which the abnormal earnings will do so is proportional to the difference between this long-run mean and the current abnormal earnings and where the constant of proportionality, or speed of adjustment coefficient, is given by $-c_{11} > 0$. Larger values of the speed of adjustment coefficient imply that abnormal earnings will be more forcefully constrained to gravitate towards its long-run mean of $\frac{-c_{12}}{c_{11}}v(t)$. Similar considerations show that the differential equation for the information variable can be stated as:

$$\frac{dv(t)}{dt} = -c_{22}\left(\frac{-c_{21}}{c_{22}}a(t) - v(t)\right) + k_2\frac{dz_2(t)}{dt} \quad (2.14)$$

This means that, apart from a stochastic component, the information variable, $v(t)$, will gravitate towards a long-run mean of $\frac{-c_{21}}{c_{22}}a(t)$. Again, the force with which it will do so is proportional to the difference between this long-run mean and the current value of the information variable and where the speed of adjustment coefficient is $-c_{22} > 0$. We have previously noted, however, that $v(t)$ captures all value relevant information which has not, as yet, been recorded in the firm's accounting reports. It thus follows that $v(t)$ is prospective in nature and that because of this it is unlikely that the abnormal earnings variable, $a(t)$, which is generally retrospective in nature, can adequately reflect or capture movements in the information variable's long run mean value. Given this, one would expect c_{22}

to be much larger than c_{21} in absolute terms and from this it follows that $\frac{c_{21}}{c_{22}}$ will have to be close to zero.

Now, here one can use integration by parts to show that the present value of the stream of future abnormal earnings will be:

$$\frac{1}{i} \int_0^{\infty} e^{-it} a(t) dt = \left[\frac{-e^{-it}}{i} a(t) \right]_0^{\infty} + \frac{1}{i} \int_0^{\infty} e^{-it} \frac{da(t)}{dt} dt$$

Evaluating the first term on the right hand of this expression shows:

$$\left[\frac{-e^{-it}}{i} a(t) \right]_0^{\infty} = \frac{a(0)}{i} - \lim_{t \rightarrow \infty} \left\{ \frac{e^{-it} E_0[a(t)]}{i} \right\}$$

Hence, if one is to progress beyond this point then, one must ensure that the expected present value of the future abnormal earnings remains finite as the period of time over which the present value is computed becomes infinitely large. Again, this is known as a transversality requirement (as in section 3 above) which ensures that the market value of the firm's equity will always remain finite (Becker, 2008). In the present context the transversality requirement takes the form:

$$\lim_{t \rightarrow \infty} e^{-it} E_0[a(t)] = 0$$

where $E_0(\cdot)$ is the expectations operator, taken at time zero. One can then take expectations across the integral defining the expected present value of the future abnormal earnings stream and thereby show:

$$E_0 \left[\int_0^{\infty} e^{-it} a(t) dt \right] = \frac{a(0)}{i} + \frac{1}{i} E_0 \left[\int_0^{\infty} e^{-it} \frac{da(t)}{dt} dt \right] \quad (2.15)$$

Now, it will be recalled from equations (2.12) and (2.13) that the abnormal earnings variable evolves in terms of the following differential equation:

$$\frac{da(t)}{dt} = c_{11}a(t) + c_{12}v(t) + k_1 \frac{dz_1(t)}{dt} \quad (2.16)$$

Thus, one can substitute this result into the expression for the present value of the firm's abnormal earnings stream as formalised by equation (2.15) in which case it follows:

$$E_0 \left[\int_0^{\infty} e^{-it} a(t) dt \right] = \frac{a(0)}{i} + E_0 \left[\frac{1}{i} \int_0^{\infty} e^{-it} (c_{11}a(t) + c_{12}v(t) + k_1 \frac{dz_1(t)}{dt}) dt \right]$$

However, since $E_0 \left[\frac{dz_1(t)}{dt} \right] = 0$ for all $t > 0$, it necessarily follows that the above result can be re-stated as:

$$E_0 \left[\int_0^{\infty} e^{-it} a(t) dt \right] = \frac{a(0)}{i} + \frac{c_{11}}{i} E_0 \left[\int_0^{\infty} e^{-it} a(t) dt \right] + \frac{c_{12}}{i} E_0 \left[\int_0^{\infty} e^{-it} v(t) dt \right]$$

One can then collect terms in the above expression and thereby show:

$$(1 - \frac{c_{11}}{i}) E_0 \left[\int_0^{\infty} e^{-it} a(t) dt \right] = \frac{a(0)}{i} + \frac{c_{12}}{i} E_0 \left[\int_0^{\infty} e^{-it} v(t) dt \right]$$

or equivalently:

$$E_0 \left[\int_0^{\infty} e^{-it} a(t) dt \right] = \frac{a(0)}{(i - c_{11})} + \frac{c_{12}}{(i - c_{11})} E_0 \left[\int_0^{\infty} e^{-it} v(t) dt \right] \quad (2.17)$$

Hence, if one is to make progress towards determining the expected present value of the firm's abnormal earnings stream then one must also determine the present value of the future stream of information variables, namely:

$$\int_0^{\infty} e^{-it} v(t) dt = \left[\frac{-e^{-it}}{i} v(t) \right]_0^{\infty} + \frac{1}{i} \int_0^{\infty} e^{-it} \frac{dv(t)}{dt} dt$$

One can again apply the transversality requirement (Becker, 2008):

$$\lim_{t \rightarrow \infty} e^{-it} E_0[v(t)] = 0$$

Moreover, taking expectations across the integral then shows:

$$E_0\left[\int_0^{\infty} e^{-it} v(t) dt\right] = \frac{v(0)}{i} + E_0\left[\frac{1}{i} \int_0^{\infty} e^{-it} \frac{dv(t)}{dt} dt\right] \quad (2.18)$$

One can then recall from equations (2.12) and (2.14) that the information variable evolves in terms of the following differential equation:

$$\frac{dv(t)}{dt} = c_{21}a(t) + c_{22}v(t) + k_2 \frac{dz_2(t)}{dt} \quad (2.19)$$

Substituting this result into equation (2.18) and using the fact that $E_0\left[\frac{dz_2(t)}{dt}\right] = 0$ for all $t > 0$ we then have:

$$E_0\left[\int_0^{\infty} e^{-it} v(t) dt\right] = \frac{v(0)}{i} + \frac{c_{21}}{i} E_0\left[\int_0^{\infty} e^{-it} a(t) dt\right] + \frac{c_{22}}{i} E_0\left[\int_0^{\infty} e^{-it} v(t) dt\right]$$

Collecting terms in the above equation shows:

$$\left(1 - \frac{c_{22}}{i}\right) E_0\left[\int_0^{\infty} e^{-it} v(t) dt\right] = \frac{v(0)}{i} + \frac{c_{21}}{i} E_0\left[\int_0^{\infty} e^{-it} a(t) dt\right]$$

or equivalently:

$$E_0\left[\int_0^{\infty} e^{-it} v(t) dt\right] = \frac{v(0)}{(i - c_{22})} + \frac{c_{21}}{(i - c_{22})} E_0\left[\int_0^{\infty} e^{-it} a(t) dt\right] \quad (2.20)$$

One can now substitute equation (2.20) into equation (2.17) and thereby show that the present value of the stream of expected future abnormal earnings will be:

$$E_0\left[\int_0^{\infty} e^{-it} a(t) dt\right] = \frac{a(0)}{(i - c_{11})} + \frac{c_{12}v(0)}{(i - c_{11})(i - c_{22})} + \frac{c_{12}c_{21}}{(i - c_{11})(i - c_{22})} E_0\left[\int_0^{\infty} e^{-it} a(t) dt\right]$$

or equivalently:

$$E_0\left[\int_0^{\infty} e^{-it} a(t) dt\right] = \frac{(i - c_{22})a(0)}{(i - c_{11})(i - c_{22}) - c_{12}c_{21}} + \frac{c_{12}v(0)}{(i - c_{11})(i - c_{22}) - c_{12}c_{21}} \quad (2.21)$$

This result shows that the present value of the stream of expected future abnormal earnings can be stated in terms of the firm's current abnormal earnings, $a(0)$, and the current value of the information variable, $v(0)$.

It will be recalled from previous sections of this chapter that the value of equity is determined by discounting the stream of future operating cash flows the firm expects to make or equivalently, by determining the present value of the dividends it expects to pay out over the life of the firm. In section 2.3 above we show that the value of equity in turn must be equal to the current book value of the firm's equity, $b(t)$, plus the present value of the future expected abnormal earnings stream, $a(t)$. If the firm is constrained to operate indefinitely within its existing investment opportunity set, it then follows that one can substitute equation (2.21) for the present value of the stream of expected future abnormal earnings into equation (2.11) and thereby re-state the expression for the present value of the stream of future operating cash flows the firm expects to make in the following terms:

$$P(t) = b(t) + \frac{(i - c_{22})a(t)}{(i - c_{11})(i - c_{22}) - c_{12}c_{21}} + \frac{c_{12}v(t)}{(i - c_{11})(i - c_{22}) - c_{12}c_{21}} \quad (2.22)$$

for all $t > 0$. Moreover, one can determine the time series properties of the present value of the stream of future operating cash flows by differentiating through the above expression, or:

$$\frac{dP(t)}{dt} = \frac{db(t)}{dt} + \frac{(i - c_{22})\frac{da(t)}{dt}}{(i - c_{11})(i - c_{22}) - c_{12}c_{21}} + \frac{c_{12}\frac{dv(t)}{dt}}{(i - c_{11})(i - c_{22}) - c_{12}c_{21}} \quad (2.23)$$

It will be recalled, however, that under the clean surplus identity as formalised through equation (2.9), that the firm records all its revenues and expenses in its profit and loss account. Moreover, from section 2.3 of this chapter we also know that the abnormal earnings attributable to equity over the instantaneous period from time t until time $(t + dt)$ will be $a(t) = x(t) - ib(t)$ where $x(t)$ is the firm's instantaneous accounting (or book) earnings and i is the cost of capital for the firm's equity. One can use this identity in conjunction with equation (2.9) and thereby show that the increment (per unit time) in the book value of the firm's equity will have to be:

$$\frac{db(t)}{dt} = a(t) + ib(t) - D(t)$$

Moreover, one can take the above expression given here for $\frac{db(t)}{dt}$ in conjunction with the equation (2.16) and equation (2.19) and substitute them into equation (2.23). This will show that the increment in the present value of the stream of future operating cash flows over the instantaneous period from time t until time $(t + dt)$ can be re-stated as:

$$\begin{aligned} \frac{dP(t)}{dt} = [a(t) + ib(t) - D(t)] + \\ \frac{(i - c_{22})[c_{11}a(t) + c_{12}v(t) + k_1 \frac{dz_1(t)}{dt}]}{(i - c_{11})(i - c_{22}) - c_{12}c_{21}} + \frac{c_{12}[c_{21}a(t) + c_{22}v(t) + k_2 \frac{dz_2(t)}{dt}]}{(i - c_{11})(i - c_{22}) - c_{12}c_{21}} \end{aligned} \quad (2.24)$$

However, we also know from the discussion following immediately on from equation (2.12) that the firm's investment opportunity set incorporates two normalising constants; namely:

$$k_1 = \frac{(i - c_{11})(i - c_{22}) - c_{21}c_{12}}{(i - c_{22})} \text{ and } k_2 = \frac{(i - c_{11})(i - c_{22}) - c_{21}c_{12}}{c_{12}}$$

This in turn will mean that the elements associated with the white noise terms in equation (2.24) will simplify to:

$$\frac{(i - c_{22}) k_1}{(i - c_{11})(i - c_{22}) - c_{12}c_{21}} \cdot \frac{dz_1(t)}{dt} = \frac{dz_1(t)}{dt}$$

and:

$$\frac{c_{12}k_2}{(i - c_{11})(i - c_{22}) - c_{12}c_{21}} \cdot \frac{dz_2(t)}{dt} = \frac{dz_2(t)}{dt}$$

respectively. Furthermore, if one uses the above expressions for the coefficients associated with the two white noise terms in conjunction with the fact that:

$$a(t) = \frac{(i - c_{11})(i - c_{22}) - c_{12}c_{21}}{(i - c_{11})(i - c_{22}) - c_{12}c_{21}} a(t)$$

then the equation (2.24) can be re-stated as:

$$\frac{dP(t)}{dt} = ib(t) - D(t) + \frac{(i - c_{11})(i - c_{22}) - c_{12}c_{21}}{(i - c_{11})(i - c_{22}) - c_{12}c_{21}} a(t) +$$

$$\frac{(i - c_{22})[c_{11}a(t) + c_{12}v(t)]}{(i - c_{11})(i - c_{22}) - c_{12}c_{21}} + \frac{c_{12}[c_{21}a(t) + c_{22}v(t)]}{(i - c_{11})(i - c_{22}) - c_{12}c_{21}} + \left(\frac{dz_1(t)}{dt} + \frac{dz_2(t)}{dt} \right) \quad (2.25)$$

If one now collects the terms in equation (2.25) involving the abnormal earnings variable, $a(t)$, then one finds:

$$\frac{[(i - c_{22})(i - c_{11} + c_{11}) - c_{12}c_{21} + c_{12}c_{21}]a(t)}{(i - c_{11})(i - c_{22}) - c_{12}c_{21}} = \frac{i(i - c_{22})a(t)}{(i - c_{11})(i - c_{22}) - c_{12}c_{21}}$$

Similarly, if one collects the terms in equation (2.25) involving the information variable, $v(t)$, then one finds:

$$\frac{[(i - c_{22})c_{12} + c_{12}c_{22}]v(t)}{(i - c_{11})(i - c_{22}) - c_{12}c_{21}} = \frac{ic_{12}v(t)}{(i - c_{11})(i - c_{22}) - c_{12}c_{21}}$$

Bringing these results together shows that equation (2.25) can be re-stated as:

$$\begin{aligned} \frac{dP(t)}{dt} = & i\left[b(t) + \frac{(i - c_{22})a(t)}{(i - c_{11})(i - c_{22}) - c_{12}c_{21}} + \frac{c_{12}v(t)}{(i - c_{11})(i - c_{22}) - c_{12}c_{21}}\right] - D(t) + \left(\frac{dz_1(t)}{dt} + \frac{dz_2(t)}{dt}\right) \end{aligned} \quad (2.26)$$

Hence, if one defines $\frac{dq(t)}{dt} = \frac{dz_1(t)}{dt} + \frac{dz_2(t)}{dt}$ as a white noise process with variance parameter $\zeta^2 = \sigma_1^2 + \sigma_2^2$ and substitutes equation (2.22) into equation (2.26), then it follows that the increment in the present value of the stream of future operating cash flows over the instantaneous period from time t until time $(t + dt)$ can be restated as:

$$\frac{dP(t)}{dt} = (iP(t) - D(t)) + \frac{dq(t)}{dt} \quad (2.27)$$

or equivalently:

$$\frac{dP(t)}{dt} - iP(t) = -D(t) + \frac{dq(t)}{dt} \quad (2.28)$$

Equation (2.27) shows that the value of equity will grow at a rate in line with its cost of capital, i , but that there will also be stochastic perturbations arising from the white noise term, $\frac{dq(t)}{dt}$.

Now, suppose one multiplies through equation (2.28) by e^{-it} , in which case it follows:

$$e^{-it} \frac{dP(t)}{dt} - ie^{-it}P(t) = -D(t)e^{-it} + e^{-it} \frac{dq(t)}{dt} \quad (2.29)$$

Note here, however, that for the left hand side of the above expression we have:

$$\frac{d}{dt}[e^{-it}P(t)] = e^{-it} \frac{dP(t)}{dt} - ie^{-it}P(t)$$

This will mean that equation (2.29) can be re-stated as:

$$\frac{d}{dt}[e^{-it}P(t)] = -D(t)e^{-it} + e^{-it} \frac{dq(t)}{dt}$$

One can then integrate across both sides of the above expression and thereby show:

$$e^{-it}P(t) = c - \int_0^t D(u)e^{-iu}du + \int_0^t e^{-iu} \frac{dq(u)}{du} du = c - \int_0^t D(u)e^{-iu}du + \int_0^t e^{-iu}dq(u) \quad (2.30)$$

where c is the constant of integration. However, setting $t=0$ in the above expression shows that $c = P(0)$ in which case equation (2.30) can be re-stated as follows:

$$e^{-it}P(t) = P(0) - \int_0^t D(u)e^{-iu}du + \int_0^t e^{-iu}dq(u)$$

Finally, one can then multiply through the above expression by e^{it} and thereby show that the general solution to the stochastic differential equation and hence, the market value of the equity security will be:

$$P(t) = P(0)e^{it} - \int_0^t e^{i(t-u)}D(u)du + \int_0^t e^{i(t-u)}dq(u) \quad (2.31)$$

Now, applying the expectations operator to the above expression shows that the expected market value of the firm's equity at time t will be:

$$E_0[P(t)] = P(0)e^{it} - \int_0^t e^{i(t-u)}D(u)du \quad (2.32)$$

Note how this result implies that if one abstracts from the payment of dividends then the market value of equity will grow at a rate in expectations which is equal to the cost of the firm's equity capital, $i > 0$. Moreover, one can use Wiener's Theorem to determine the variance of the market value of equity; namely (Davidson & Tippett, 2012, pp. 159-162):

$$\text{Var}_0[P(t)] = \sigma^2 \int_0^t e^{2i(t-u)}ds = \frac{\sigma^2}{2i}(e^{2it} - 1) \quad (2.33)$$

Since a Taylor series expansion shows that $e^{2it} \approx 1 + 2it$ it follows that for small t the above expression for the variance reduces to:

$$\text{Var}_0[P(t)] \approx \sigma^2 t$$

Likewise, it may also be shown that for small t the variance associated with instantaneous increments in the market value of equity is:

$$\text{Var}_0[dP(t)] \approx \sigma^2 dt$$

which is an inter-temporal constant independent of the current market value, $P(t)$, of the equity security. This runs counter to the commonly held belief that the variance associated with increments in an economic variable will become larger as the variable grows in magnitude (Cox et al., 1985). Moreover, the above result shows that the variance of the price of the equity security becomes more uncertain the longer one looks into the future. This is because the exponential term, e^{2it} , grows in magnitude as t becomes larger. Finally, under this model, the market value of the firm's equity, $P(t)$, will be normally distributed with a mean given by equation (2.32) and a variance defined by equation (2.33). It is important to emphasise, however, that there is nothing in this model which will prevent $P(t)$

from becoming negative. One can see this by observing how the white noise term, $\frac{dq(u)}{du}$, in equation (2.31) can vary over the entire real line. This in turn will mean that there is a non-trivial probability that:

$$P(t) = P(0)e^{it} - \int_0^t e^{i(t-u)}D(u)du + \int_0^t e^{i(t-u)}dq(u) < 0$$

In most industrialised countries, however, the liability of shareholders is limited to the original capital they contribute when the shares are first issued by the firm. This will mean that the Ohlson (1995) model, as developed in this section of the chapter, cannot provide a completely satisfactory basis for the valuation of a firm's equity. In Chapter 3 we shall amend the Ohlson (1995) model to prevent $P(t)$ from becoming negative. For the moment, however, we summarise the literature which deals with the empirical validity of the Ohlson (1995) model as formulated in this section of the dissertation.

2.5 Empirical Implications of the Ohlson (1995) Model

The Garman and Ohlson (1980) sequential valuation model, as subsequently interpreted by Ohlson (1995) and Feltham and Ohlson (1995) amongst others, has justifiably been described by Bernard (1995, p. 773) as "... among the most important developments in capital markets research in the last several years ..." and by Lundholm (1995, p. 749) as a "... landmark work in financial accounting." The Ohlson (1995) model has the important attribute of providing a clear economic rationale for the proper conduct of empirical work dealing with the relationship between equity prices, the figures appearing in corporate financial statements and other information variables such as the size of a firm's order book and the general state of the industry and/or economy in which the firm operates. Given this, our main objective in this section of the chapter is to review the literature which assesses the empirical validity of the Ohlson (1995) equity valuation model. We begin our analysis of the literature by summarising the three most often cited papers that assess the empirical validity of the Ohlson (1995) model; namely, Dechow et al. (1999), Myers (1999) and Morel (2003). In the next section, we then

move on to summarise some of the other important developments in the literature of this area.

Dechow et al. (1999) base their empirical analysis of the Ohlson (1995) model on 50,133 firm-year observations of U.S. annual earnings and book values covering the period from 1976 to 1995 as taken from the COMPUSTAT file, the CRSP file and the I/B/E/S file. They express the view that accounting-based valuation models applied in previous empirical research are simple and somewhat restrictive versions of the Ohlson (1995) model. Thus their empirical analysis mainly focuses on the unique features of the Ohlson (1995) model; that is, models incorporating the “other information” variable and the persistence parameters associated with abnormal earnings and the “other information” variable. As previously noted, in the Ohlson (1995) model the future abnormal earnings and the other information variable evolve in terms of a first-order vector system of stochastic differential (or difference) equations. Dechow et al. (1999) begin their analysis by noting that the empirical implementation of the Ohlson (1995) linear information dynamics is based on data for three variables; namely, the book value of equity, $b(t)$, abnormal earnings, $a(t)$, and the information variable, $v(t)$. The first two of these variables - $b(t)$ and $a(t)$ - are readily available from a firm’s published financial statements and are easily measured. Dechow et al. (1999) define earnings to be after special charges but before extraordinary items. Unfortunately, this is a definition that contradicts the clean surplus requirement on which the Ohlson (1995) model is based. Beaver (1999, p. 37) criticises both the definition of earnings employed by Dechow et al. (1999) and the empirical work based on it by noting that “the basis for forecasting only a subset of earnings lacks motivation and [leads to] a value representation based on only a subset of earnings [which] does not necessarily hold [up in practice]”. Additionally, an earnings variable that excludes extraordinary items, might lead to lower estimation of the earnings persistence coefficient as transitory factors are not taken into account. However, empirical work conducted by other authors shows that this is not an issue of any great empirical significance (Myers, 1999; Collins et al., 1999; Morel, 2003).

Dechow et al. (1999) emphasise that an important characteristic of the Ohlson (1995) model which distinguishes it from the residual income version of the discounted dividend model, is that the evolution of all the important determining variables is modelled through a vector system of first order difference equations as follows:

$$x_{t+1}^a = \omega x_t^a + v_t + \varepsilon_1(t+1) \quad (2.34)$$

$$v_{t+1} = \gamma v_t + \varepsilon_2(t+1) \quad (2.35)$$

where x_{t+1}^a is the abnormal earnings over the period from time t until time $(t+1)$, v_{t+1} is the information variable that captures information relevant to future abnormal earnings which has not as yet been incorporated into the firm's accounting records and $\varepsilon_1(t+1)$ and $\varepsilon_2(t+1)$ are stochastic error terms with means of zero. Thus, in Dechow et al.'s (1999) empirical analysis, abnormal earnings follow a mean reversion process and the persistence of abnormal earnings is estimated through the speed of adjustment parameter, ω . Dechow et al. (1999) estimate the speed of adjustment parameter using all available observations over the period from 1950 until 1995. The speed of adjustment (or persistence) measure, γ , associated with the information variable, v_t , is based on equation (2.35) and uses the same procedure that is employed to estimate the persistence measure, ω , associated with the abnormal earnings variable. The numerical value associated with v_t is determined by substituting abnormal earnings into equation (2.37) as given below.

Combining equations (2.34) and (2.35) with the abnormal earnings model in equation (2.11b), shows that the expected present value of an equity security's future dividend stream can be stated as follows (Dechow et al., 1999, p. 6):

$$P_t = b_t + \alpha_1 x_t^a + \alpha_2 v_t \quad (2.36)$$

Where the valuation weights are given by:

$$\alpha_1 = \frac{\omega}{1 + r - \omega}$$

and:

$$\alpha_2 = \frac{1 + r}{(1 + r - \omega)(1 + r - \gamma)}$$

This is the discrete time analogue of the continuous time interpretation of the Ohlson (1995) model as given by equation (2.22).

Attempts at incorporating the information variable into the equity valuation process date as far back as Beaver et al. (1980). Dechow et al. (1999) broach this issue by employing analysts' forecasts of a firm's future earnings in conjunction with equations (2.34) and (2.35) to estimate the information variable, v_t . Here one can take expectations through equation (2.34) in which case we have:

$$E_t[x_{t+1}^a] = v_t + \omega x_t^a$$

where $E_t(\cdot)$ is the expectations operator taken at time t . It then follows that:

$$v_t = E_t[x_{t+1}^a] - \omega x_t^a \quad (2.37)$$

will provide an estimate of the information variable v_t , and where $E_t[x_{t+1}^a]$ is the expected abnormal earnings over the period from time t until time $(t + 1)$. Here $E_t[x_{t+1}^a]$ is defined as the difference between the consensus analyst forecast, $f(t)$, of a firm's earnings over the period from time t until time $(t + 1)$ and the product of the book value of the firm's equity at time t multiplied by its cost of capital; that is:

$$E_t[x_{t+1}^a] \equiv f(t) - rb_t \quad (2.38)$$

In particular, Dechow et al. (1999, p. 11) define $f(t)$ to be “the I/B/E/S consensus forecast of earnings for year $t + 1$ measured in the first month following the announcement of earnings for year t .” Combining equations (2.37) and (2.38), it then follows that the information variable, v_t , can be estimated as:

$$v_t = E_t[x_{t+1}^a] - \omega x_t^a = f(t) - r b_t - \omega x_t^a \quad (2.39)$$

where r denotes the cost of the firm’s equity capital (on a per unit time basis). Prior research is cited in Dechow et al. (1999) that shows empirical tests are insensitive to discount rates that range from a low of 9% up to a high of 15% (per annum). Moreover, Miller and Modigliani (1966) estimate the cost of capital for one industry for three years and come to the conclusion that the assumption of a constant cost of capital across all firms and time is the best that researchers can do. They note, in particular, that using time varying discount rates does not have much of an impact on the estimates of a security’s intrinsic (or fundamental) value. Given this, Dechow et al. (1999) apply a 12% discount rate to all the firms employed in their empirical analysis since this approximates the average historical return on US equities up to the point in time when their paper was published.

Having described the procedures Dechow et al. (1999) employ to obtain their data for the b_t , x_t and v_t , variables and the three parameters, ω , γ and r , we now summarise the empirical results they obtain in relation to the forecasting ability of the Ohlson (1995) linear information dynamics. We begin by noting how Dechow et al. (1999) find that models which incorporate the other information variable, v_t , generate better estimates of the one period ahead abnormal earnings variable, x_{t+1}^a , than models which do not incorporate the information variable. Their findings, as summarised in Panel A of Table 4 of Dechow et al. (1999, p. 21) (see below), show that if the other information variable, v_t , is excluded from their empirical analysis then the mean absolute forecast error⁶ associated with the prediction of x_{t+1}^a

⁶ All forecast errors have been deflated by the market value of the given firm’s equity (Dechow et al., 1999, p. 21).

ranges from 0.076 to 0.087 whilst the mean square forecast error ranges from 0.028 to 0.033 - depending on the assumption which is made about the speed of adjustment (that is, persistence) parameter, ω . The first assumption invoked by Dechow et al. (1999, p.7) takes the persistence measure to be $\omega = 0$. The second assumes a persistence measure of $\omega = 1$. The third assumption employs an unconditional estimate of the persistence measure, ω^u , based on the entire sample of firms employed in the Dechow et al. (1999) empirical analysis. The fourth assumption uses a conditional estimate of the persistence measure, ω^c , for each firm based on the firm's operating accruals, its dividend policy and other industry-specific variables.

Panel B of Table 4 summarises the Dechow et al. (1999) results for the prediction of x_{t+1}^a when the information variable, v_t , is included in the forecasting process. Note how the results summarised in this section of Table 4 show that incorporating the other information variable reduces the mean absolute forecast error and the mean square forecast error to 0.052 and 0.015, respectively. Thus, the Dechow et al. (1999) results summarised in Table 4 highlight the importance of the other information variable in the forecasting of a firm's future abnormal earnings and by implication, to the explanation of contemporaneous equity prices using the Ohlson (1995) equity valuation model.

Table 4
Relative forecasting ability of alternative modes for predicting next year's abnormal earnings

Panel A: Predictions for models ignoring 'other information', computed as

$$E_t[x_{t+1}^a] = \omega x_t^a$$

	Mean forecast error	Mean absolute forecast error	Mean square forecast error
$\omega = 0$	-0.029	0.087	0.033
$\omega = 1$	0.006	0.081	0.032
$\omega = \omega^u$	-0.008	0.077	0.030
$\omega = \omega^c$	-0.006	0.076	0.028

Panel B: Prediction for models incorporating 'other information', computed as

$$E_t[x_{t+1}^a] = f_t^a$$

	-0.032	0.052	0.015
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Dechow et al. (1999) then go on to assess the Ohlson (1995) equity valuation model's ability to explain contemporaneous stock prices. Dechow et al. (1999, p. 23) again report that models which incorporate the other information variable, v_t , generate better estimates of contemporary stock prices than models which ignore the information variable. Their findings, as summarised in Panel A of Table 5 of Dechow et al. (1999, p. 23), show that when the other information variable is excluded from the Ohlson (1995) valuation model, then the mean absolute forecast error ranges from 0.461 to 0.519 whilst the mean square forecast error ranges from 0.284 to 0.363 - again, depending on the particular assumption which is made about the persistence parameter, ω . In contrast, when the information variable is included as a component of the Ohlson (1995) valuation model, then the results summarised in Panel B of Table 5 show that the mean absolute forecast error ranges from 0.402 to 0.445. This shows that incorporating the information variable marginally improves the Ohlson (1995) valuation model's ability to explain contemporary stock prices.

Table 5
Relative forecasting ability of alternative modes for explaining contemporaneous stock prices

Panel A: Price estimates for models ignoring 'other information', computed as

$$P_t = b_t + \frac{\omega}{1 + r - \omega} x_t^a$$

	Mean forecast error	Mean absolute forecast error	Mean square forecast error
$\omega = 0$	0.291	0.461	0.284
$\omega = 1$	0.378	0.519	0.363
$\omega = \omega^u$	0.320	0.461	0.284
$\omega = \omega^e$	0.326	0.465	0.291

Panel B: Price estimates for models incorporating 'other information', computed as

$$P_t = b_t + \frac{\omega}{1 + r - \omega} x_t^a + \frac{1 + r}{(1 + r - \omega)(1 + r - \gamma)} v_t$$

$(\omega = 0, \gamma = 0)$	0.285	0.445	0.266
$(\omega = 1, \gamma = 0)$ and $(\omega = 0, \gamma = 1)$	0.227	0.402	0.232
$(\omega = \omega^u, \gamma = 0)$ and $(\omega = 0, \gamma = \gamma^u)$	0.278	0.427	0.248
$(\omega = \omega^u, \gamma = \gamma^u)$	0.259	0.419	0.241

Dechow et al. (1999) reach a number of conclusions based on the information summarised in Table 4 and Table 5. The first of these is that first order forecasting models for abnormal earnings which ignore the information variable perform best when forecasts are based on the conditional persistence parameter ω^c . However, Dechow et al. (1999, p. 24) also note that the Ohlson (1995) model based on the conditional persistence parameter, ω^c , provides rather poor estimates of stock prices in comparison to the valuation models which employ a persistence measure of zero or ω^u - as evidenced by the results summarised in Panel A of Table 5. Dechow et al. (1999, p. 24) attribute the disparity in the performance of the model in estimating the next period's abnormal earnings and stock price to the possibility that "stock prices do not reflect rational expectations of future abnormal earnings." This disparity, however, also raises the possibility that there are internal inconsistencies in the Ohlson (1995) model.

Dechow et al. (1999, p. 24) also note from Table 5 that equity valuation using a persistence measure of $\omega = 1$ for the abnormal earnings variable and a persistence measure of $\gamma = 0$ for information variable provides the most satisfactory explanation of contemporary stock prices. Dechow et al. (1999, p. 10) note that when $\omega = 1$ and $\gamma = 0$, the Ohlson (1995) model returns an equity value equal to the capitalisation in perpetuity of the analysts' one period ahead earnings forecast; that is, $P_t = \frac{f_t}{r}$.

In other words, the equity valuation process does not involve the book value variable and equity value is simply determined by the earnings variable alone. A simple earnings capitalisation model that excludes the book value of equity, however, is likely to be biased because prior empirical work shows that the information carried by book value will normally make a significant contribution to the market value of a firm's equity (Ou & Sepe, 2002). In other words, the market value of equity is, in general, a function of both earnings and book value (Butgstahler & Dichev, 1997). That the model does not involve book value, whilst at the same time providing the most accurate forecast of stock prices also raises the possibility that the basic premises on which the Ohlson (1995) model is founded are fundamentally flawed. Overall Dechow et al. (1999) conclude that the most

favourable interpretation of the Ohlson (1995) valuation model under-estimates the market value of a typical firm's equity in the order of at least 20% and probably higher. This is supported by the fact that the mean equity valuation forecast error as summarised in Panel B of Table 5 varies from 0.227 to 0.285, depending on the assumptions which are made about the persistence parameters, ω and γ .

In general, Dechow et al. (1999) find that consistent with the Ohlson (1995) linear information dynamics, the first-order autoregressive process for the residual income variable provides a good approximation to future abnormal earnings. Moreover, models incorporating the other information variable outperform models excluding the other information variable in the sense that they provide better forecasts of future abnormal earnings. Models including the other information variable are also more successful in explaining contemporaneous stock prices in comparison with valuation models that ignore the information variable. The fact the models that incorporate the other information variable outperform models that ignore it indicates that the other information variable provides incremental information about the value of a firm's equity. Dechow et al. (1999, pp. 3, 25), however, also conclude from their empirical work that there is a fundamental flaw in the Ohlson (1995) valuation model in that its parsimonious nature will mean that it cannot provide a complete explanation for the evolution of stock prices.

As mentioned above, the empirical analysis summarised in Dechow et al. (1999) focuses only on the unique features of the Ohlson (1995) model; in particular, the incorporation of the other information variable into the Ohlson (1995) linear information dynamics. In the Ohlson (1995) model the other information variable, v_t , is defined as a proxy for value-relevant events that have not as yet been recorded in the firm's accounting records. In a semi-strong or strongly efficient market, all publicly available information will be reflected in the market prices of equity securities. "All publicly available information" is taken as including both the financial information which appears in a firm's published financial statements and the financial and non-financial information which has not as yet been reflected in the firm's financial statements. While the market reacts to new information about the firm's current or future earnings, accounting records only recognise

quantifiable cash flows and other transactions that have actually taken place. This in turn will mean that equity valuation models which ignore the other information variable must by construction lead to an incomplete description of the way equity prices are determined.

The information variable will be of particular importance in the Ohlson (1995) equity valuation model for industries where there is rapid technological change. In such industries market value is created by a firm's current and prospective investment activities and the financial effects of these investment activities will not be fully reflected in a firm's accounting records for a considerable period after the initial investment costs are incurred. Amir and Lev (1996) take the U.S. cellular industry as an exemplar of such an industry. They note how the rapid technological developments which occur in this industry will lead to up-front research and development costs and expenses that depress book values and earnings in the early years of an investment project but which will also lead to high levels of cash flows and profitability in the latter years of the project. This in turn will mean that non-financial information such as the current levels of a firm's market penetration and the firm's longevity could be significant indicators of the long term financial effects (cash flows and profitability) of its current investment activities. As such, equity valuation models that exclusively rely on information obtained from a firm's accounting records will provide little and even misleading information to investors. Amir and Lev (1996) test this hypothesis by regressing U.S. cellular stock prices on book values and earnings alone and find that neither of their coefficients is statistically significant. They note how their sample is characterised by firms that enjoy high market expectations while consistently having negative earnings and low book values caused by heavy investment start-up costs (customer acquisition, brand development, infrastructure development, etc.) and revolutionary technological development before any revenues are received. Their findings are consistent with Hayn's (1995) empirical results that the income statements of loss making firms are much less informative than the income statements of profit making firms.

Amir and Lev (1996) then conduct further empirical analysis in which they combine traditional financial variables with non-financial indicators in order to explain stock prices of the U.S. cellular firms comprising their sample. Their findings show that when non-financial information is combined with book value and earnings in their regression procedures that the estimated valuation coefficients associated with both the non-financial and the financial variables (book value and earnings) are all highly statistically significant. Their findings both confirm the hypothesis that non-financial information can have a significant impact on equity values in industries where there is rapid technological development and also demonstrates the biases which can arise as a result of the omitted variables problem in the empirical work conducted in this area of the literature. Whilst Amir and Lev (1996) study the impact that nonfinancial information can have on equity values in an industry specific situation, they also argue that non-financial information will impact on equity values in all industrial classifications to varying degrees. The quantification of non-financial information can often be problematic and this in turn will mean that it is not an easy matter to determine the valuation impact of such information.

It has been shown in Amir and Lev (1996) that non-financial information (that is the Ohlson (1995) other information variable, v_t) can have a significant impact on the market value of a firm's equity. However, as discussed in Dechow et al. (1999), the incorporation of the other information variable in the Ohlson (1995) linear information dynamics only results in marginal improvements in the cross-sectional explanation of contemporary equity prices. One possible reason for this, as Myers (1999) claims, is that there are internal inconsistencies in the interpretation that Dechow et al. (1999) apply to the Ohlson (1995) linear information dynamics. Hence, to assess the empirical validity of the Ohlson (1995) model, Myers (1999) suggests that some important modifications need to be made to the interpretation which Dechow et al. (1999) apply to the Ohlson (1995) model. Here, Myers (1999) notes that besides the clean surplus identity, the Ohlson (1995) model is based on two key additional assumptions: first, that the residual income (abnormal earnings) and information variables evolve in terms of a first-order vector system of

autoregressive processes; second, that the information variable reflects only information relating to the firm's future abnormal earnings which is not captured by its current abnormal earnings. Thus the persistence of abnormal earnings is captured by the autoregressive parameter associated with the abnormal earnings variable in the first-order vector system of autoregressive equations that defines the Ohlson (1995) linear information dynamics. Moreover, Myers (1999) also claims that the Ohlson (1995) model does not specify what the other information variable is, and because of this "it is not possible to explicitly control for all possible [interpretations of] v_t ." (Myers, 1999, p. 8). Cesar et al. (2004) also state that there is no proper way to capture the information variable especially as Ohlson (1995) does not provide any formal guidance as to how to interpret the information variable. Myers (1999) goes on to note that because of this it is common in the empirical literature to ignore the information variable in the Ohlson (1995) model. Myers (1999), however, outlines four different ways in which to interpret the Ohlson (1995) linear information dynamics and he demonstrates how one can evaluate the empirical performance of each interpretation. As with most of the literature in the area, the first three of Myers' (1999) interpretations of the Ohlson (1995) linear information dynamics do not include v_t . However, in the fourth interpretation v_t is proxied by an "orders backlog" variable.

Myers (1999) also argues that applying a time-varying cost of capital should track stock prices more effectively than employing a constant cost of capital across firms. The cost of capital for each firm-year in Myers (1999) is comprised of the risk free rate of interest plus a risk premium for each firm, estimated using the Fama and French (1997) three factor model. The mean cost of capital across the firms comprising the Myers (1999) sample is 12.13% and the median cost of capital is 11.78% (per annum). The empirical work is based on non-financial firm-year data obtained from the COMPUSTAT file between 1975 and 1996.

The first Linear Information Model (LIM1) evaluated in Myers (1999) is the Ohlson (1995) model without the other information variable. As the information variable is excluded, Myers (1999) expects a non-zero intercept term both in the

autoregressive process for the residual income variable and also, for the Ohlson (1995) implied price formula. If the model provides a reasonable description of firm equity value, then the ratio of the implied Ohlson (1995) price and the actual market price should be equal to unity. The median ratio, however, is only 0.411, which means LIM1 only reflects about 40% of the actual market price of equity. Moreover, the parameters of LIM1, that is, the coefficients obtained from a cross-sectional linear regression of actual equity market value on book value (0.464) and residual income (1.358) are inconsistent with the equilibrium price coefficients implied by the median parameters for book value (1.000) and residual income (0.265) in the system of linear information dynamics. Myers' (1999) results suggest that LIM1 fails on average to provide an adequate characterisation of the market price of equity. Myers (1999) explains that the failure of LIM1 to provide an adequate characterisation of the market price of equity is due to the underestimation of the present value of expected future residual income under the conservative accounting procedures which characterise accounting practice. He attempts to address the impact of accounting conservatism in other models presented in his paper.

The second Linear Information Model (LIM2) proposed in Myers (1999) includes the effect of accounting conservatism on book value in the residual income autoregressive process. The coefficients on the book value variable are expected to be positive under conservative accounting. However, the empirical work summarised in Myers (1999) shows that most of the coefficients on the book value variable are negative. This result shows that LIM2 fails to incorporate the effects of accounting conservatism into the equity pricing process. Moreover, the median ratio of the Ohlson (1995) model estimate of equity value under LIM2 to the actual market price of equity shows that the Ohlson (1995) model only captures about 64% of the market price of equity. Again, the coefficients obtained from a cross-sectional linear regression of actual equity market value on book value (0.543) and residual income (0.481) are inconsistent with the equilibrium price coefficients implied by the median parameters for book value (0.909) and residual income (0.033) under the LIM2 system of linear information dynamics. Myers' (1999)

also notes that estimates of equity value based on LIM2 perform no better than estimating equity values based on book value alone.

Myers (1999) recognises that the effects of conservatism could be more complex than what can be captured by simply incorporating book values into LIM2. Given this Myers (1999) defines a third system of linear information dynamics, LIM3, which includes both income and book value effects in order to capture accounting conservatism. Unfortunately, most of the coefficients on the book value variable are again negative. This indicates that LIM3 also fails to capture the effects of accounting conservatism on the equity pricing process. Moreover, there is again an inconsistency between the coefficients on the information variables in the price-level regression and the equilibrium coefficients implied by the median parameters for book value and residual income under the LIM3 information dynamics. This in turn shows that LIM3 performs no better than LIM2 and LIM1.

The distinguishing feature of the three LIMs discussed to date is that they all exclude the Ohlson (1995) other information variable, v_t . Here it will be recalled that v_t captures all value-relevant information that has been disseminated in the market but that has not as yet been incorporated into a firm's financial statements. Myers (1999) argues that the omission of v_t from LIM1, LIM2 and LIM3 could be a significant factor in the failure of his empirical analysis to explain contemporaneous stock prices. He then observes how order backlogs will depress current residual income but increase the residual income in subsequent periods. Given this, Myers (1999) defines a new set of linear information dynamics, LIM4, which augments LIM2 by including order backlogs as a proxy for the other information variable, v_t . Myers (1999) argues that the coefficient associated with the order backlog variable in the residual income autoregressive process ought to be positive. His empirical results, however, show that the median coefficient is equal to zero. This in turn implies that the order backlog variable has a negligible impact on future abnormal earnings. Moreover, there is again an inconsistency between the coefficients on the information variables in the price-level regression and the equilibrium coefficients implied by the median parameter estimates of the

LIM4 information dynamics. Myers (1999) also notes that the R^2 coefficients associated with the price-level regressions decline as the complexity of the valuation models increase.

Overall, all linear information models tested in Myers (1999) fail to capture the true stochastic relationship between the market value of a firm's equity and its determining variables. Myers (1999, p. 26) attributes this failure to the fact that "there are too few observations to make precise estimates of the time-series parameters." He also notes that "the time-series processes of [the] accounting information [variables] are likely to be nonstationary...". However, as with Dechow et al. (1999) the empirical results summarised in Myers (1999) may indicate that the Ohlson (1995) linear information dynamics represent an incomplete description of the equity valuation process in the sense that it omits some of the important value-relevant variables. In particular, it is highly likely that the omission of value-relevant variables will cause biased parameter estimates in the regression equations.

Morel (2003) argues that the unsatisfactory empirical results reported in Dechow, et al. (1999) and Myers (1999) are the consequence of other serious methodological errors and internal inconsistencies. For example, Morel (2003, p. 1342) claims that the inter-temporally constant cost of capital, 12%, across all firms assumed by Dechow et al. (1999) contradicts the fact that the cost of capital varies over the sample period. Morel (2003, p. 1342) points out that this is an arbitrary assumption which "reduces the variability of the data, thereby increasing the variance of OLS estimators." She also notes that Fama and French (1997), amongst others, have demonstrated empirically that the cost of capital hinges on firm size and also varies stochastically over time. Ignoring these factors induces an "errors in variables" problem into the Dechow et al. (1999) regression procedures which again, will result in biased estimates of the affected parameters. Whilst Myers (1999) seeks to address these latter issues by estimating each firm's cost of capital using the Fama and French (1997) three factor model Morel (2003), points out that a firm's cost of capital must be simultaneously estimated with the other parameters of the Ohlson (1995) model if parameter estimation is to be consistent and efficient. Moreover,

Morel (2003) notes that Dechow et al. (1999) and Myers (1999) both fail to test for the stationarity of the time series data employed in their empirical analysis. If as Morel (2003) suspects their data is characterised by the existence of a unit root, then the OLS regressions they employ will have been conducted with non-stationary time series data and will yield biased estimates of all coefficients.

To address the weaknesses in the Dechow et al. (1999) and Myers (1999) empirical analyses, Morel (2003) estimates all parameters endogenously and allows firm costs of capital to vary over the sample period. Morel (2003) uses three methodologies to assess the Ohlson (1995) model's ability to explain contemporaneous stock prices. In the first methodology, the auto-regressive process for the abnormal earnings variable and the Ohlson (1995) equity valuation model are estimated by ordinary least squares (OLS) for each firm separately. However, Morel (2003) makes the point that the coefficients in the abnormal earnings autoregressive process bear a non-linear relationship to each other. Given this, the second test methodology uses non-linear least squares and non-linear seemingly unrelated regression procedures to estimate the parameters of the Ohlson (1995) model. This methodology compares the earnings persistence and the risk premium parameters for each firm estimated from the auto-regressive process for abnormal earnings with the earnings persistence and risk premium parameters estimated from the Ohlson (1995) equity valuation model. If the Ohlson (1995) equity valuation model is internally consistent then the parameters estimated from the auto-regressive process for the abnormal earnings variable should be equivalent to those estimated from the Ohlson (1995) equity valuation model itself. For the third test methodology, the Ohlson (1995) model is estimated as a system of restricted non-linear equations where the parameters in the auto-regressive process for abnormal earnings and the Ohlson (1995) equity valuation model are forced to be equal. This methodology aims to test whether the Ohlson (1995) model yields significant parameter values when the earnings persistence and risk premium parameters are constrained to be equal. However, the empirical results obtained from these three methodologies are problematic in terms of the support they provide for the Ohlson (1995) model. For instance, the parameters generated by the first methodology show different signs to those expected in the Ohlson (1995)

model. In addition, the parameters associated with the lagged book values which are very important variables in the Ohlson (1995) equity valuation model, are not statistically significant. Empirical results generated by the second methodology show that the parameters estimated from the auto-regressive process for abnormal earnings and the risk premium are significantly different from the parameters directly estimated through the Ohlson (1995) model. For the third methodology, when the parameters in the auto-regressive process for abnormal earnings and the Ohlson (1995) equity valuation model are restricted to be equal, the empirical results show that the parameter estimates for the risk premium, which is a fundamental valuation parameter in the Ohlson (1995) model, is not statistically significant. Taken as a whole, the empirical results summarised in Morel (2003) imply that the Ohlson (1995) model is at best, empirically problematic.

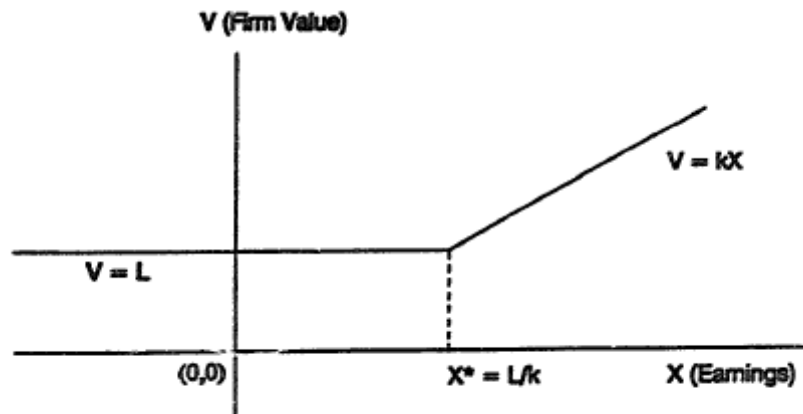
In conclusion, none of the information dynamics models empirically implemented in Dechow et al. (1999), Myers (1999) and Morel (2003) result in Ohlson (1995) equity valuation models that are completely satisfactory. This in turn means that the praise many researchers have heaped on the Ohlson (1995) model is premature. Moreover, the attempts which have been made to refine the Ohlson (1995) model have yielded only marginal improvements in the internal consistency of the model and/or the explanation of contemporaneous equity prices. An important consideration here is that the Ohlson (1995) model imposes a linear relationship between the market value of a firm's equity and its determining variables. However, Ou and Penman (1989), Burgstahler and Dichev (1997) and Penman (2001) amongst many others have all pointed out that there are significant limitations in the traditional linear models that associate accounting information with stock prices. The unsatisfactory nature of the linear relationships imposed by these traditional linear modelling techniques should act as an incentive for researchers to re-examine the validity of the assumptions on which they are based.

2.6 Other Empirical Work in the Area

Book or accounting figures that appear in corporate financial statements are regarded as an important source of information for investors; particularly in

relation to the resource allocation decisions that they have to make. They are also an important source of data for accounting researchers who use accounting information as explanatory variables in the equity valuation models they develop. We have previously noted how much of the empirical work conducted in this area is based on a linear relationship between accounting information and contemporaneous stock prices. However, Lev's (1989) exhaustive review of the empirical work shows that correlation coefficients obtained from the standard linear models that regress stock prices against earnings are extraordinarily low and unstable in time. Lev (1989) also points out that there is a fundamentally non-linear relationship between stock prices and earnings and that it is this which might be the source of the weak association that researchers have found between earnings and prices. Recently, compelling empirical evidence shows that a convex and highly non-linear relationship exists between equity prices and the summary measures that appear on corporate financial statements. Moreover, this empirical evidence is largely compatible with the hypothesis that the non-linear relationships which arise in this area of the literature are caused by the strategic and operational (adaptation) options that firms have to modify or even abandon their current investment opportunity sets. In this section, we summarise the important empirical evidence presented on this matter by Hayn (1995), Burgstahler and Dichev (1997), Ashton et al. (2003) and others which show that a fundamentally non-linear relationship exists between market value of equity and the accounting variables appearing in corporate financial statements.

Hayn (1995) introduces a simple model which defines the value of the firm as the product of expected earnings per share in perpetuity, X , and a multiplier, k . However, when X falls below a threshold level X^* , the firm's value would be equal to its liquidation value, V . The predicted relationship between firm value and earnings with the liquidation option value is depicted in Figure 2 of Hayn (1995, p. 133) as follows:

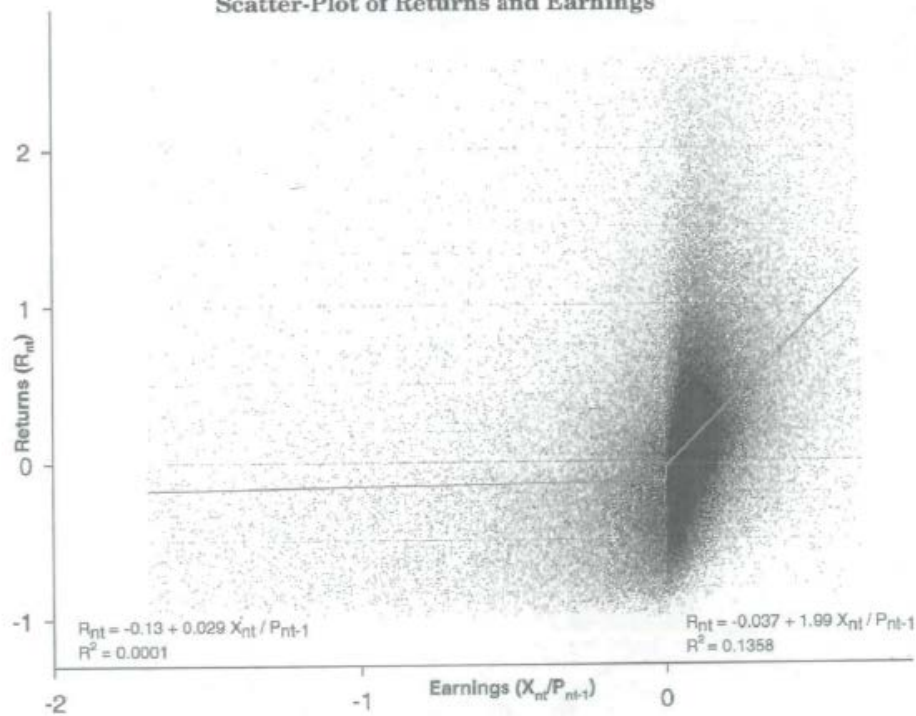


Hayn (1995) indicates that if the simple model is correct then the coefficients obtained from the standard linear models that regress stock prices against earnings would be downwardly biased, because the earnings of loss making firms will be uncorrelated with firm value. In regressions of stock returns on the earnings to price ratio, Hayn (1995) finds that the estimated coefficient of the earning to price ratio for a sample of 75,878 firm-year pooled U.S. data covering the period from 1962 until 1990 is 0.95. For the 14,512 loss firm-years comprising her sample, however, the estimated coefficient associated with the earning to price ratio is 0.01. For the 61,366 profit firm-years, the estimated coefficient of the earning to price ratio is 2.62. The results are consistent with the implication of the simple model that the coefficient on the earnings variable generated from a pooled regression with the inclusion of loss making firms is significantly dampened by the impact of the loss making firms. Moreover, earnings exhibit significantly stronger explanatory power with respect to the stock returns of the profit firm-year group with an R^2 of 16.9%. However, for the loss firm-year group the R^2 is a miserly 0.00%. Hayn (1995) concludes that a firm's past and current losses may signal that the future earnings are likely to be sufficiently low to make the abandonment option attractive. Given this, investors will not determine the intrinsic value of a loss making firm using its earnings alone since they have the option of putting the firm into liquidation at some future point in time of their choosing. The lack of sensitivity that the stock prices of loss making firms show to the firm's earnings is confirmed by the empirical tests Hayn (1995) conducts on the relationship between stock returns and earnings changes. These are summarised in Panel B of Table 5

of Hayn (1995) and show that for profit firm-years, the coefficient on earning changes increases from 2.98 for a one-year period to 3.72 for a ten-year cumulating period. In contrast, for loss firm-years, the coefficient on earning changes increases from 0.31 for a one-year period to 1.21 for a ten-year cumulating period. The effect of loss firm-years on the regression R^2 is also evident. The R^2 values of the regression estimated for aggregate loss firm-years range from 2.1% for a one-year period to 13.8% for a ten-year cumulating period, whilst the R^2 values of the regression estimated for profit firm-years range from 7.3% to 45.2% in the corresponding periods. Hayn (1995) concludes from these results that while the stock price movements of profit firm-years are correlated with the changes in their reported earnings, the stock price movement of loss making firm-years appears to be independent of the changes in their reported earnings. Hayn's (1995) empirical results generally show that the earnings variable has a non-linear relationship with stock returns. This non-linearity arises from the existence of the liquidation option held by shareholders when a loss making firm's earnings contain only limited information about its intrinsic (that is, fundamental) value.

Figure 1 in Easton (1999, p. 407) provides a scatter-plot of the data upon which Hayn's (1995) empirical analysis is based. This figure illustrates that a non-linear relationship exists between earnings on the x-axis and stock returns on the y-axis, which is consistent with the simple model depicted in Figure 2 of Hayn (1995).

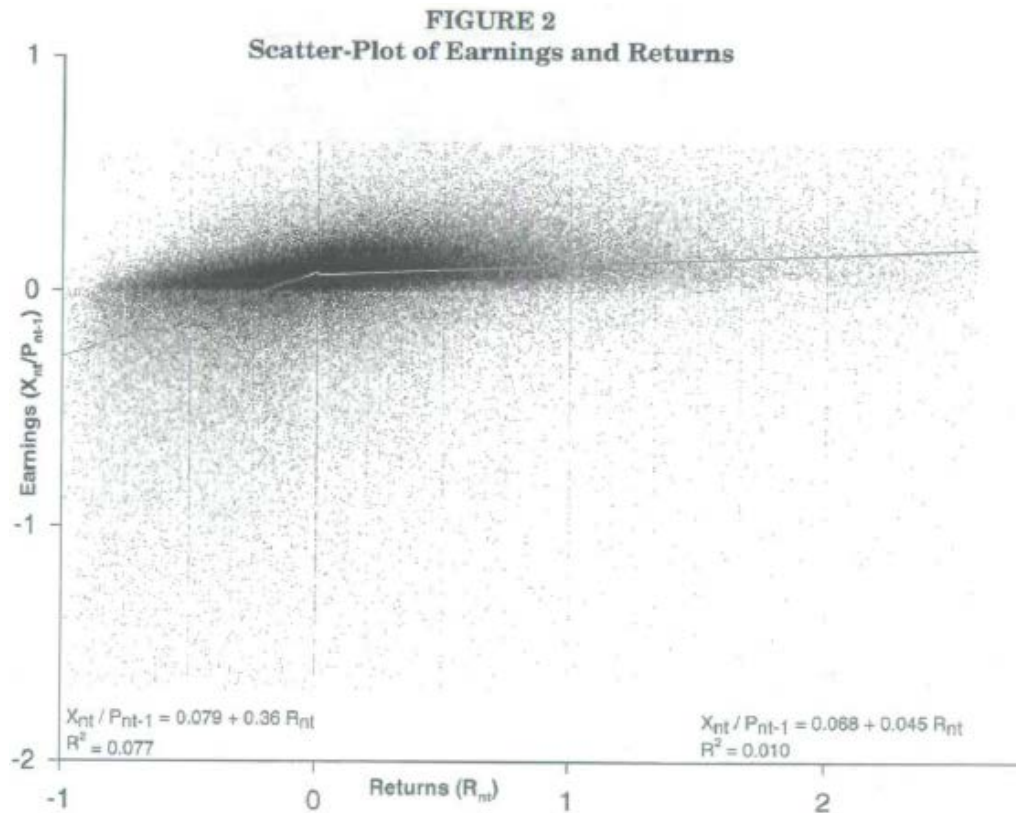
FIGURE 1
Scatter-Plot of Returns and Earnings



The literature in this area also identifies several other forms of adaptation (real) options that could make a significant contribution to the market value of a firm's equity and also lead to the existence of a weak association between earnings and stock prices. As previously noted, Amir and Lev (1996) observe that for growing and technology-based firms - in particular, those in the cellular and biotechnology industry - the association between earnings and stock prices is very weak. A possible explanation for this is given by Dixit and Pindyck (1994, p. 111); namely, that firms in the "electronics, telecommunications, and biotechnology industry" are likely to have highly volatile and therefore unpredictable future cash flows. This in turn will mean that a considerable part of the market value of their equity will be comprised of investment and growth options. When there is evidence of these growth options in a firm's financial statements (as there will be, for example, when an electronics firm has capitalised its research and development costs), then one would expect there to be a non-linear relationship between the market value of the firm's equity and the information appearing in its published financial statements. The contribution which growth options can make to the overall market value of

equity will be further discussed in our review of the Zhang (2000) equity valuation model in Chapter 3.

Another possible explanation for the observed non-linear relationship which exists between the summary measures that appear in a firm's financial statements and the market value of its equity arises from the conservative accounting that characterises accounting practices. In particular, Basu (1997) observes that in conservative accounting, earnings reflect bad news more quickly than good news. To test this prediction of asymmetric timeliness, he uses negative and positive returns of the fiscal year as proxies for bad news and good news respectively. Basu (1997) predicts that the sensitivity of earnings to negative returns is higher than that of the earnings to positive returns. This means that in the earnings on returns regressions, the coefficient on the earnings variable and its associated R^2 coefficient will be higher for firms with bad news (that is, with negative returns) than those with good news (that is, with positive returns). The results of the pooled cross-sectional regressions of price deflated earnings on contemporaneous annual returns shows that the R^2 for 17,790 firms with negative returns is 6.64% and the coefficient on returns is 0.275, while the R^2 for 25,531 firms with positive returns is 2.09% and the coefficient on returns is 0.059. Figure 2 in Easton (1999, p. 408) is the scatter-plot of the data upon which Basu's (1997) empirical analysis is based. We notice here that this figure again shows a distinct non-linear relationship between returns on the x-axis and earnings on the y-axis which is consistent with the findings of Hayn (1995), though from an entirely different perspective.



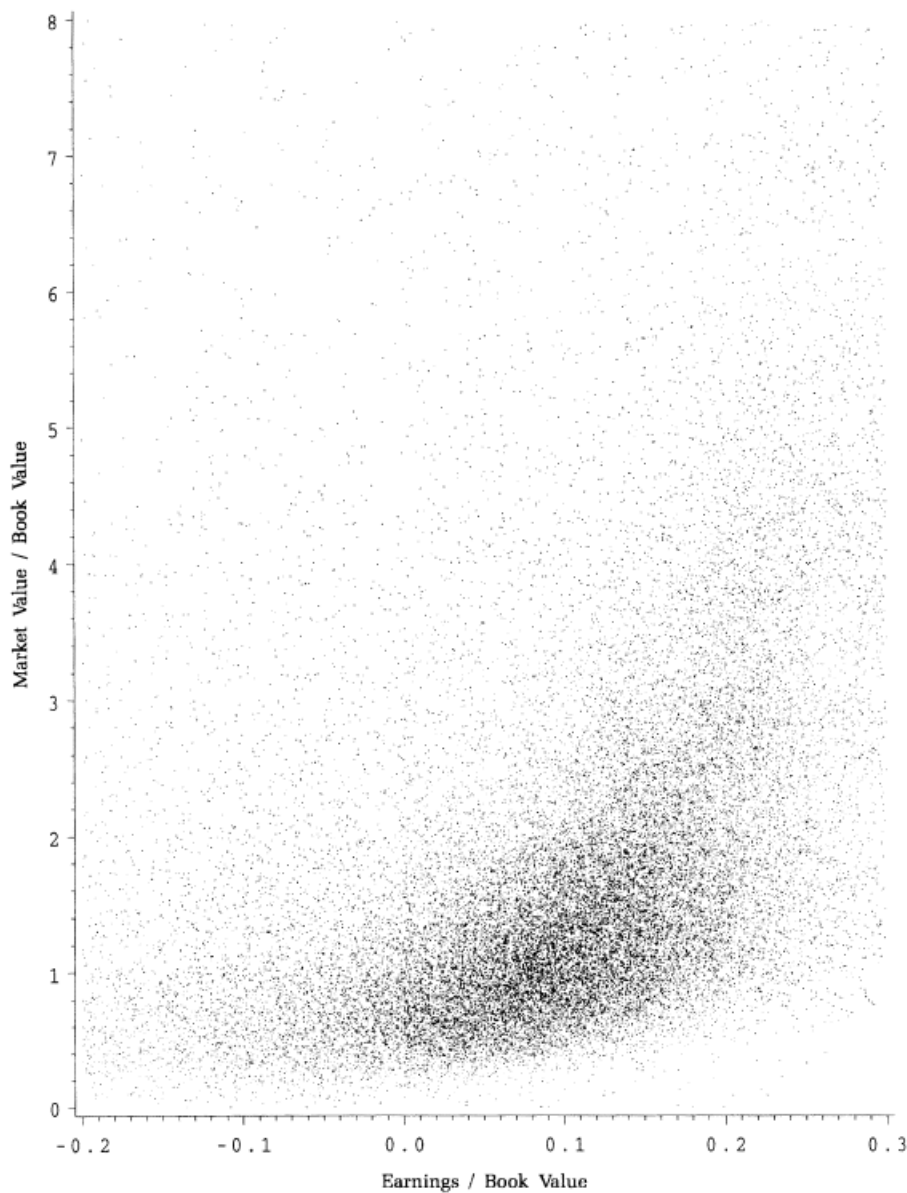
Burgstahler and Dichev (1997) also demonstrate that there will have to be a non-linear relationship between the information summarised in a firm's financial statements and the market value of its equity. In particular, they argue that the market value of a firm's equity cannot be simply determined by discounting its expected future cash flows. Recall that this discounting of the expected future cash flows is exactly the procedure that the Ohlson (1995) model employs to value a firm's equity. Burgstahler and Dichev (1997), however, contend that the market value of a firm's equity will be comprised of two main components. The first of these is called the recursion value of equity. The recursion value of a firm's equity is determined under the assumption that the firm will continue indefinitely into the future with its current investment opportunity set. A firm's recursion value is the expected present value of its future dividend payments and is the component of equity value that is captured by the Ohlson (1995) equity valuation model. However, the parsimonious assumption on which the Ohlson (1995) model is based does not allow this model to capture the managerial flexibility that is normally available to a firm. Here, Burgstahler and Dichev (1997, p. 188) identify a second

component of equity value; namely, the real option (or adaptation) value of equity. This is the option value that arises when the firm can alter its investment opportunity set. These adaptation options include contingent scenarios like the liquidation of part or all of the firm, sell-offs, spin-offs, divestitures, CEO changes, mergers, takeovers, bankruptcies, restructurings and new capital investments (Jensen & Ruback, 1983). The availability of these adaptation options gives firms the possibility of reducing or eliminating negative outcomes or achieving higher earnings. If a firm has options to adapt its resources to more profitable alternative uses, then one would expect them to be reflected in the market value of the firm's equity. The particular focus of Burgstahler and Dichev (1997, p. 194), however, is on the liquidation option; that is, the value of the option that a poorly performing firm may have to go into liquidation and distribute the proceeds of the liquidation to its equity holders. Here, Burgstahler and Dichev (1997, p. 194) use book value to approximate the adaptation value of equity since at liquidation - when the recursion value of equity will be very low - book value is largely independent of a firm's current operations and is similar or identical to the liquidation value of the firm. Moreover, since the expected present value of the future dividend payments a firm will make must be equal to the book value of its equity plus the expected present value of its abnormal (that is, residual) earnings stream (as in section 2.3 above), Burgstahler and Dichev (1997) use current earnings as a proxy for the recursion value of equity.

Burgstahler and Dichev (1997) note that when a firm's resources are successfully used, the earning to book value ratio will be high and earnings are the more important determinant of the firm's equity value. In contrast, when the earnings to book value ratio is low, book value is the more important determinant of the firm's equity value. This in turn will mean that the relationship between a firm's market value and its accounting information - namely, book value and earnings - is not homogeneous cross-sectionally but varies with the level of the ratio of earnings to book value. This in turn will mean that there will have to be a non-linear relationship between the market value of a firm's equity and its earnings and book value. The apparent non-linear relationship between the market value of equity and the earnings attributable to equity (both scaled by book value) is graphed in Figure

2 in Burgstahler and Dichev (1997, p. 199). This figure encompasses a sample of over 45,000 US firm-years as extracted from the COMPUSTAT file and covering the period between the years 1976 and 1994. Note that when earnings are low the market value of a firm's equity is insensitive to earnings changes. As earnings gradually increase in magnitude, however, the market value of a firm's equity reacts more and more strongly to earnings changes.

FIGURE 2
Market Value/Book Value versus Earnings/Book Value
1976–1994



The Burgstahler and Dichev (1997) empirical analysis of the relationships encapsulated in Figure 2 are based on two fundamental propositions. First, if book value is held constant Burgstahler and Dichev (1997) predict that equity value will be a convex function of earnings; second, if earnings is held constant, they also predict that equity value will be a convex function of book value. The two propositions are tested by invoking the following two regression specifications (Burgstahler & Dichev, 1997, p. 195):

$$\frac{P(t)}{b(t)} = \gamma_1 \frac{b(t)}{b(t)} + \gamma_2 \frac{x(t)}{b(t)} + \varepsilon^* = \gamma_1 + \gamma_2 \frac{x(t)}{b(t)} + \varepsilon^* \quad (2.40)$$

$$\frac{P(t)}{x(t)} = \gamma_1 \frac{b(t)}{x(t)} + \gamma_2 \frac{x(t)}{x(t)} + \varepsilon^{**} = \gamma_2 + \gamma_1 \frac{b(t)}{x(t)} + \varepsilon^{**} \quad (2.41)$$

As previously defined, $P(t)$ is the market value of a firm's equity, $b(t)$ is the book value of a firm's equity and $x(t)$ is the earnings attributable to a firm's equity, all at time t . Moreover, γ_1 is the estimated coefficient relating to book value and γ_2 is the estimated coefficient relating to earnings. Finally, ε^* and ε^{**} are stochastic error terms. Burgstahler and Dichev (1997) implement piece-wise linear regression procedures by dividing all observations into three groups with equal numbers based on the magnitude of the earnings to book value ratios [for regression (2.40)] and on the book value to earnings ratio [for regression (2.41)] to determine the strength of the convexity relationship which exists between the market value of equity and book value and earnings.

The empirical results based on the regression model (2.40) are summarised in Table 3 of Burgstahler and Dichev (1997, p. 201). The regressions summarised in this Table show that as the earnings to book value ratios increase, then the coefficients relating to book value, γ_1 , generally decline in magnitude. In contrast, the coefficients relating to earnings, γ_2 , generally increase in magnitude. The empirical results generated by the regression model (2.41) are summarised in Table 5 of Burgstahler and Dichev (1997, p. 208) and are generally consistent with the results summarised in their Table 3. The regressions summarised in Table 5 show

that as the book to earnings ratios increase, then the coefficients relating to book value, γ_1 , generally increase in magnitude. In contrast, the coefficients relating to earnings, γ_2 , generally decrease in magnitude. The overall conclusion that Burgstahler and Dichev (1997) draw from their empirical analysis is that there is a non-linear relationship between market value of equity and the earnings and book value variables. They also show that when earnings are large, then the valuation coefficient associated with earnings is relatively high whilst the valuation coefficient associated with book value is relatively low. In contrast, when earnings are low, then the valuation coefficient associated with earnings is relatively low whilst the valuation coefficient associated with book value is relatively high. As noted above, Burgstahler and Dichev (1997) use the earnings attributable to a firm's equity as a proxy for the recursion value of its equity and book value as a proxy for adaptation value. These latter suppositions will mean that when a firm's earnings are large, then the recursion value of its equity will also be large and will thus comprise the dominant component of the firm's equity value. However, when earnings are low, then the adaptation value of equity plays a more significant role in determining the overall market value of a firm's equity.

Further evidence about the impact that real options can have on equity values is to be found in the paper by Barth et al. (1998). Their analysis is based on the hypothesis that the balance sheet provides information about the liquidation value of firms whilst the income statement provides information about the discounted value of the firm's future operating cash flows. Given this, they predict that as the firm's financial health deteriorates, then the importance of the balance sheet in equity valuation will increase whilst the importance of the income statement will decrease. This in turn will mean that the valuation weights which the market applies to the book value of equity and net income will change accordingly. They test this prediction by analysing the relationship between the market value of equity, the book value of equity and the profits of 396 U.S. bankrupt firms in each of the five years leading up to bankruptcy. The data employed in their empirical work is taken from the COMPUSTAT file covering the period from 1974 until 1993. In

particular, they implement the following cross-sectional regression model for each of the five years preceding bankruptcy:

$$MVE_{it} = a_0 + a_1BVE_{it} + a_2BVE_NEG_{it} + a_3NI_{it} + a_4NI_NEG_{it} + e_{it} \quad (2.42)$$

Here MVE_{it} is the market value of the firm's equity t years before bankruptcy, BE_{it} is the book value of equity t years before bankruptcy and NI_{it} is the net income earned by the firm over the year that is t years out from bankruptcy. The regression equation allows the coefficients on positive book value and net income to differ from those on negative book value and net income. BVE_NEG_{it} (NI_NEG_{it}) is the product of BVE_{it} (NI_{it}) and a dummy variable that has a value of unity if BVE_{it} (NI_{it}) is negative but has a value of zero otherwise. Finally, a_0 , a_1 , a_2 , a_3 and a_4 are coefficients to be estimated and e_{it} is a stochastic error term. Barth et al. (1998, p. 9) expect a_4 to be negative because the limited liability of ordinary shares suggests that each incremental dollar of losses is negatively and decreasingly related to share prices.

The empirical results obtained from the regression model formalised by equation (2.42) are summarised in Panel A of Table 2 of Barth et al. (1998, pp. 14-15). The results show that a_3 , which is the coefficients on NI , falls from 4.00 in year $(t - 5)$ to 0.00 in year $(t - 1)$. In contrast, a_1 , which is the coefficient on the BVE , increases from 0.41 in year $(t - 5)$ to 0.84 in year $(t - 1)$. In addition, the coefficient a_4 as expected, remains negative across all five years of the empirical analysis. Overall, the test results are consistent with the hypothesis that as a firm approaches bankruptcy then the book value of its equity becomes an increasingly important determinant of the market value of equity value, whilst its earnings decline in significance.

Table 2

Summary statistics from regressions of market value of equity on equity book value and net income and tests of incremental explanatory power for a sample of Compustat firms that delisted from Compustat because of bankruptcy between 1975–93. Year is relative to delisting.

Panel A: $MVE_{it} = a_0 + a_1BVE_{it} + a_2BVE_NEG_{it} + a_3NI_{it} + a_4NI_NEG_{it} + e_{it}$															
	Year $t - 5$			Year $t - 4$			Year $t - 3$			Year $t - 2$			Year $t - 1$		
	coef.	t-stat		coef.	t-stat		coef.	t-stat		coef.	t-stat		coef.	t-stat	
Intercept	17.58	5.20		19.75	8.38		15.40	8.12		14.09	6.72		8.95	5.20	
NI	4.00	3.34		2.92	6.15		3.31	6.51		0.98	1.70		0.00	0.01	
BVE	0.41	2.55		0.42	6.52		0.49	7.83		0.64	9.36		0.84	4.85	
NI_NEG	-0.45	-3.25		-0.28	-5.23		-0.35	-6.04		-0.12	-1.81		-0.03	-0.19	
BVE_NEG	-0.03	-0.07		-0.32	-1.04		-0.10	-0.32		-0.40	-1.95		-0.53	-2.80	
Adj. R^2	0.80			0.78			0.84			0.65			0.53		
No. of obs.	208			255			290			352			396		

Barth et al. (1998) also test whether the empirical findings from their sample of bankrupt firms will hold for a larger, pooled sample of firms. In this test, the sample data is comprised of all non-bankrupt publicly traded firms on COMPUSTAT with net income, total assets and book values of equity in excess of \$1 million over the period from 1988 until 1993. In particular, they implement the following regression model which allows the coefficients on equity book value and net income to vary with a firm's financial health:

$$MVE_{it} = a_0 + a_1 LO_{it} + a_2 BVE_{it} + a_3 BVE_LO_{it} + a_4 NI_{it} + a_5 NI_LO_{it} + e_{it} \quad (2.43)$$

As previously, MVE_{it} is the market value of the firm's equity t years before bankruptcy, BE_{it} is the book value of equity t years before bankruptcy and NI_{it} is the net income earned by the firm over the year that is t years out from bankruptcy. The regression equation allows the coefficients on book value and net income in the higher financial health category to differ from those in the lower financial health category. Here BVE_LO_{it} is the product of BVE_{it} and a dummy variable that has a value of unity if the firm is classified as being in the lower financial health category and a value of zero otherwise. Likewise, NI_LO_{it} is the product of NI_{it} and the same dummy variable. Finally, a_0 , a_1 , a_2 , a_3 and a_4 are coefficients to be estimated and e_{it} is a stochastic error term. Regression results in Panel B of Table 4 (see below) in Barth et al. (1998, p. 21) show that, a_3 the incremental coefficient on book value for firms of lower financial health is 0.48 and a_5 , the incremental coefficient on net income is -5.62. The results imply that book value carries more weight than net income in determining the market value of equity for firms in the lower financial health category. The coefficient on book value for the less financially healthy firms is $0.93 (= 0.45 + 0.48)$ and the coefficient on net income coefficient for these firms is $5.09 (= 10.71 - 5.62)$. In contrast, the coefficient on book value for more financially healthy firms is 0.45 and the coefficient on net income for these firms is 10.71.

Panel B: Summary statistics from regressions of market value of equity on net income and book value of equity, using fixed-effects estimation with fixed year effects.

$$MVE_{it} = a_0 + a_1 LO_{it} + a_2 BVE_{it} + a_3 BVE_LO_{it} + a_4 NI_{it} + a_5 NI_LO_{it} + e_{it}$$

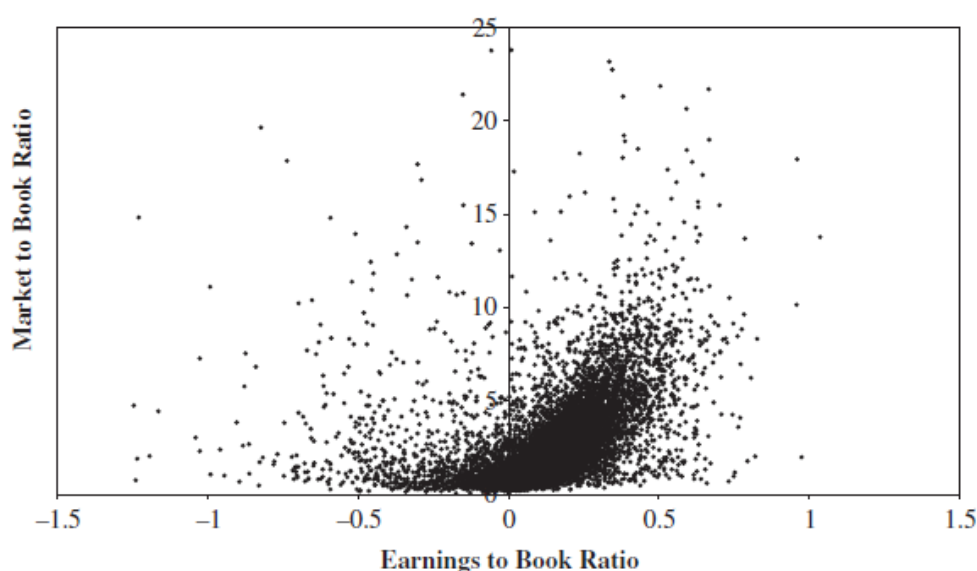
	Predicted sign	Coefficient (t-statistic)
Intercept $_LO$		− 72.27 (− 1.88)
NI	+	10.71 (16.93)
NI_LO	−	− 5.62 (− 11.10)
BVE	+	0.45 (3.96)
BVE_LO	+ [−]	0.48 (3.96)
Adj. R^2		0.82

These results are compatible with the Burgstahler and Divheev (1997) hypothesis that the real (adaptation) value of equity will be “closely related” to its book value in instances where there is a high probability that the firm will be forced into bankruptcy. The non-linear relationship between the market value of equity and earnings is captured in their regression equations by the “two state” dummy variable, namely, BVE_NEG_{it} , and NI_NEG_{it} in the regression model (2.42) (or BVE_LO_{it} and NI_LO_{it} in the regression model (2.43)). However, Burgstahler and Divheev (1997) note that as a firm’s earnings become extraordinarily negative, they eventually lose all relevance in equity valuation. Here it is important to note that the “two state” dummy variable cannot reflect the situation where the earnings variable becomes completely irrelevant to the market value of equity. Given this, the Barth et al. (1998) regression procedures represent, most likely, a very preliminary attempt to capture the non-linear relationship which exists between the market value of a firm’s equity and its earnings and book values. Moreover, Yee (2000, p. 229), refers to the empirical findings in Barth et al. (1998) as “earnings complementarity”. He argues that “earnings convexity and complementarity are not independent phenomena. Whenever Modigliani-Miller dividend [policy irrelevance] holds, earnings convexity and complementarity tend to occur

together ... Burgstahler and Dichev (1997)'s earnings convexity and Barth et al.'s (1998) complementarity are two different guises of the same phenomena." In Yee (2000) an adaptation-adjusted valuation model is developed which reflects earnings convexity and complementarity. We will discuss the Yee (2000) model in more details in Chapter 3.

Collins et al. (1999) also raise doubts about the validity of basing empirical work on the assumption of a linear relationship between the market value of a firm's equity and its earnings and book value. In particular, they divide their sample into profit making and loss making firms. They then conduct a price-earnings regression based on only the profit making firms. Their empirical results show that the coefficients associated with the earnings variable are significantly positive with a mean adjusted R^2 values of 55%. They then augmented their regression model by including both the earnings and the book value variables as components of the price-level regression, again based on only profit making firms. However, including book value as a component of the regression model results in only a moderate improvement in explanatory power with an increase in the adjusted R^2 from 55 to 61%. Collins et al. (1999) also conduct a price-earning regression based only on loss making firms. Their empirical results show that the coefficients associated with the earnings variable are negative and the mean adjusted R^2 value is only 9%. They again augment their regression model by including both earnings and the book value as components of the price-level regression. Their regression results show that for loss making firms book value has a strong positive association with stock prices with the adjusted R^2 rising from 9% when book value is excluded to 42% when book value is included as a component of the regression equation. Collins et al. (1999) thus conclude that earnings are the dominant determining factor in the explanation of market prices for profit making firms, whilst book value contains only limited information about equity values. However, book value has substantial incremental explanatory power beyond earnings in equity valuation for loss making firms. In particular, book value can be used as a proxy for abandonment option value for firms which are contemplating the termination of their existing operations.

Ashton et al. (2003) graph the relationship between the price to book value of equity ratio and the earnings to book value of equity ratio for 12,547 U.K. firm-years covering the period from 1988 until 1998. They find that a highly convex relationship exists between these two ratios as depicted in their Figure 2 (Ashton et al. 2003, p. 429), something that is consistent with the results summarised in Burgstahler and Divhev (1997). They also develop an aggregation theorem which provides a theoretical justification for the non-linear relationship that appears to exist between the market value of a firm's equity and its earnings and book value. We will discuss the Ashton et al. (2003, p. 429) model in further detail in Chapter 3.



Considerations of space mean that we can only summarise the more important papers dealing with non-linearity issues in equity valuation here. We would emphasise, however, that there is a steadily growing volume of papers that provide further empirical evidence on this issue. Di-Gregorio (2006), for example, shows that there is a highly non-linear and convex relationship between the market value of equity, earnings and the book value of equity for German and Italian firms over the period from 1995 to 2005. Kwon (2009) finds similar results for Korean equity securities. The Kwon (2009) empirical results also show that real options make a significant contribution to the overall market value of Korean firm equity value. Moreover, Hodgson and Stevenson-Clarke (2000) find that the explanatory power

of earnings and cash flows can be improved significantly by using a non-linear valuation function for Australian Stock Exchange listed equity securities.

2.7 Conclusion

In this chapter we review and synthesise the literature dealing with the determination of the intrinsic or fundamental value of an equity security. The fundamental principle of valuation we have developed in this chapter is that equity value can be determined by discounting the future dividends a firm expects to pay (the Discounted Dividend model) or alternatively, by discounting its future operating cash flows (the Discounted Cash Flow model). However, recent theoretical developments in equity valuation link the cash flows earned and the dividends paid by firms to the accounting information appearing in their published financial statements. This in turn means that equity value can be determined without reference to a firm's dividend payments or its expected future cash flows. Under the clean surplus identity, for example, the value of a firm's equity can be viewed as the sum of the current book value of equity and the present value of the expected future residual income stream attributable to equity. This is known as the Residual Income Valuation (RIV) Model or alternatively, the Abnormal Earnings Model. The Ohlson (1995) equity valuation model, which is developed from the RIV model, is now regarded as one of the most important achievements in accounting based valuation theory in recent years. The Ohlson (1995) model assumes that the increment in a firm's abnormal earnings depends on the current level of its abnormal earnings and an "other information" variable which captures all the information relevant to the value of a firm's equity that has not as yet been incorporated into the firm's accounting records. We have shown in this chapter that the evolution of the abnormal earnings and other information variable can be developed in terms of a first order vector system of stochastic differential equations. This system of differential equations is often referred to as the Ohlson (1995) linear information dynamics or equivalently, the firm's investment opportunity set. The importance of the Ohlson (1995) model stems from the linear information dynamics which link current information to future abnormal earnings - and this

leads to a valuation procedure that does not require an explicit forecast of future dividends or cash flows.

Our summary of the literature in this area pays particular attention to the empirical validity of the linear information dynamics proposed by Ohlson (1995) and others. Here we discuss the three most often cited papers (Dechow et al., 1999; Myers, 1999; Morel, 2003) which test the Ohlson (1995) model either directly or under certain modifications. These papers all show that the Ohlson (1995) model appears to under-estimate actual equity value by about 20%. The empirical results summarised in these papers also highlight the internal inconsistency of the Ohlson (1995) linear information dynamics. An important consideration here is that the Ohlson (1995) model imposes a linear relationship between the market value of a firm's equity and its determining variables. Given this, there is an urgent need for researchers to re-examine the validity of the assumptions on which the Ohlson (1995) linear modelling techniques are based.

Here we would note that there is a mounting volume of analytical and empirical research which demonstrates that there is a non-linear relationship between the market value of a firm's equity and the information recorded in its published financial statements. In particular, the affected empirical evidence shows that the relative importance of earnings versus book value in explaining equity value varies with the level of earnings. This variation underlies the highly non-linear relationship which appears to exist between equity prices and the information recorded in a firm's financial statements. This in turn will mean that the market value of a firm's equity cannot be simply determined by discounting its expected future cash flows. Specifically, recent developments in equity valuation theory show that the market value of a firm's equity is comprised of two main components. First, there is the recursion value of equity. Recursion value is determined under the assumption that the firm will continue with its current investment opportunity set indefinitely into the future. The second component is the adaptation value of equity. Adaptation value captures the option value associated with a firm's ability to alter its investment opportunity set in order to employ its resources in alternative and more profitable ways. The market value of a firm's equity is characterised by

the complementary interaction of the recursion and adaptation values of its equity - both of which vary in accordance with the firm's profitability.

In Chapter 3, we will summarise the modelling procedures that have been used in the literature to determine the non-linear equity valuation relationships that arise out of the interaction between the recursion and adaptation values of a firm's equity. In particular, we will review how option-style models determine the market value of a firm's equity in terms of the information recorded in its published financial statements. We will also discuss the equity valuation implications of momentum and acceleration as it affects the variables comprising a firm's investment opportunity set.

Chapter 3

Real (Adaptation) Option Valuation, Momentum and Acceleration

3.1 Introduction

The principal objective of this chapter is to introduce a theoretical framework for determining the impact that the real options available to firms and the momentum and acceleration of the variables comprising a firm's investment opportunity set will have on the market value of a firm's equity. We begin our analysis in section 3.2 by briefly discussing the differences between the traditional Discounted Cash Flow and Discounted Dividend models of equity valuation and the option-style models which incorporate the real options available to firms as a component of overall equity value. Section 3.3 then goes on to develop the analogy between financial options and the real options available to firms as a precursor to our analysis of the contribution that real options can make to the overall market value of a firm's equity. Section 3.4 then summarises how real option value has been included as an element of equity value in the models of Zhang (2000), Yee (2000) and Ashton et al. (2003) which are the principal models published in this area of the literature. The common feature shared by all these models is that they show how the market value of a firm's equity is comprised of two complementary valuation components. The first of these is determined by discounting the stream of expected future cash flows the firm is expected to earn under the assumption that it will apply its existing investment opportunity set indefinitely into the future. The second element of equity value arises out of the options the firm has to change or modify its existing investment opportunity set. In section 3.5 the focus of our analysis changes to the investment opportunity set employed by firms. In particular, we discuss how the momentum and acceleration of variables comprising a firm's investment opportunity set and stochastic variations in the real option value arising out of a firm's ability to change or modify its investment opportunity

set, impact on the overall market value of the firm's equity. Section 3.6 concludes and provides a brief summary of the chapter.

3.2 Traditional Valuation Models and Option-style Models

In the previous chapter we have developed equity pricing formulae based on the assumption that the firm is constrained to apply its existing investment opportunity set indefinitely into the future. Here, traditional corporate finance theory suggests that the Discounted Cash Flow model (DCF) should be used to justify investment proposals and also, to determine the value of a firm's equity. We have also come to an important conclusion; namely, that the present value of the firm's expected future operating cash flows must be equal to the book value of the firm's equity plus the present value of its expected future abnormal earnings. Under either approach, the estimated cash flows from an investment project are discounted to their present value at a discount rate which is comprised of the risk free rate of interest plus a premium for risk. Hence, the underlying principle of all the traditional models is the basic Net Present Value rule (NPV). According to the NPV rule, when an investment in a firm or capital project has a positive net present value, this investment will be implemented, otherwise it will be rejected. According to Dixit and Pindyck (1994), however, traditional investment (valuation) theory does not recognise the irreversibility, uncertainty and choice of timing associated with an investment project. For example, the NPV rule is based on the demonstrably false assumption that capital expenditure can be completely recovered should the economic environment turn out to be unfavourable. The NPV rule also assumes that the investment is a "now or never" decision. In the real world, however, most investments are at least partially irreversible; that is, the expenditure can only be partly recovered and even then, at a substantial cost. The ability to choose the timing of an investment so as to reduce uncertainty significantly affects the feasibility and desirability of the proposed investment and profoundly changes the conventional NPV value calculated under the assumption of the "now or never" investment proposition. In other words, traditional models derived from the orthodox theory of equity valuation based on the NPV rule exclude the flexibility value that may be present in investment proposals. In the

real world, besides the choice of investment timing, firms will normally have the option of changing or modifying their investment opportunity sets in order to use the resources available to them in alternative and potentially more profitable ways. There are a variety of ways in which firms can exercise the option to change their investment opportunity sets; for example, liquidations, sell-offs, spin-offs, divestitures, CEO changes, mergers, takeovers, bankruptcies, restructurings, new capital investments, and other options including patents, licenses and rights to natural reserves. As Brealey and Myers (1991, p. 511) note:

“Real options ... allow managers to add value to their firm,
by acting to amplify good fortune or mitigate loss.”

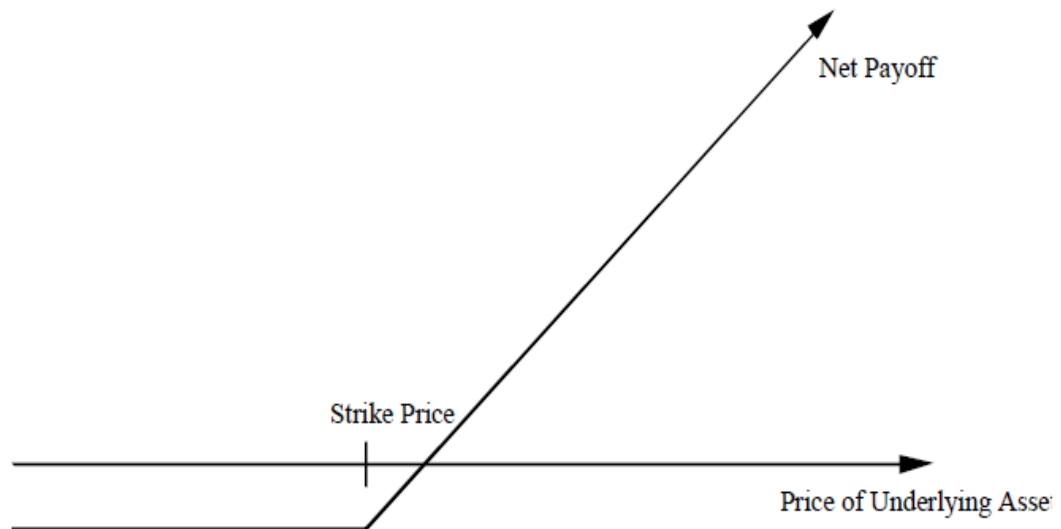
The options possessed by firms mean that they will enjoy a higher market value than the present value calculated from discounting the fixed cash flows implied by an irreversible investment opportunity set. Given this, it is hardly surprising that the studies summarised in the previous chapter, all of which are based on linear valuation models which ignore the options that firms have to change their investment opportunity sets, fail to find a satisfactory relationship between accounting (book) based information and the market value of corporate equity. Hence, in this chapter we demonstrate how the options which firms have to change their investment opportunity sets may be valued for some of the commonly encountered scenarios in the literature.

3.3 Meaning and Existence of Real Option

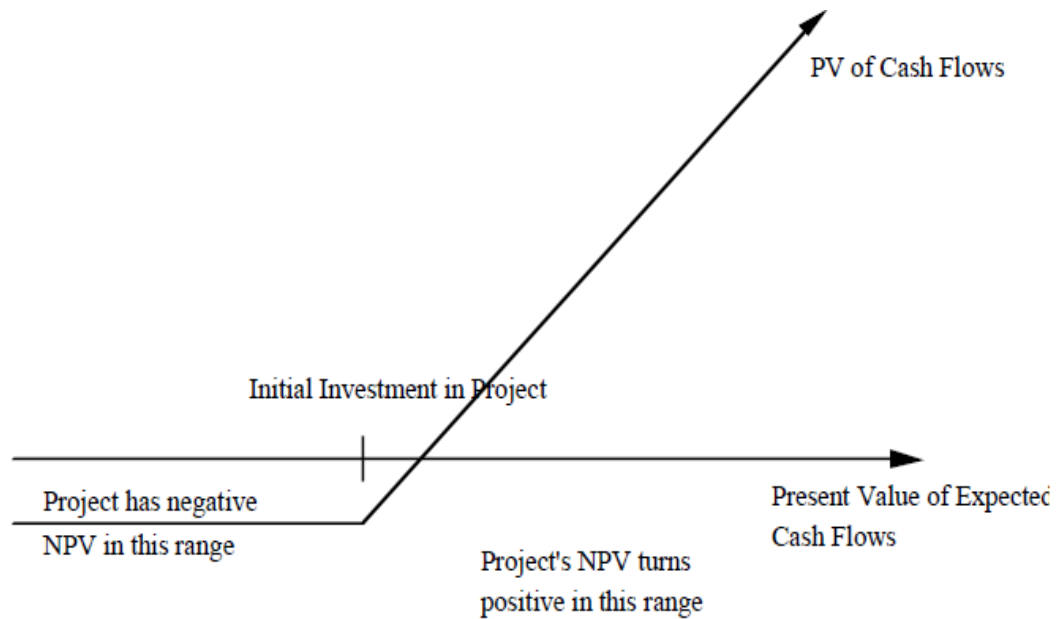
In this section, we highlight the similarities between real options and financial options in order that we might understand why real options have value. We also demonstrate the significant contribution that real options can make to the overall market value of a firm's equity.

We begin by considering a firm which has an opportunity to invest in a new capital project. In other words, the firm has the right but not the obligation to implement the capital project either immediately or at some future point of time. Now, here recall that a financial call option also gives the holder the right, but not the

obligation, to purchase the underlying asset at a predetermined price (the strike or the exercise price) before or on the expiration date of the option. The buyer has to pay a price to gain this right. In particular, the pay-off diagram for a financial call option can be illustrated as follows:



When the price of the underlying asset falls below the strike price - as will be the case on the left hand side of the horizontal axis in the above pay-off diagram - then the holder of the option will not exercise the option and will lose the premium paid to purchase the call option. However, when the price of the underlying asset exceeds the strike price then the holder of the option will exercise the option and will make a profit equal to the difference between the price of the underlying asset and the sum of the strike price and the premium paid to purchase the call option. The above pay-off diagram for a financial call option can also be used to describe the value of an investment opportunity available to a firm by merely re-labelling the axes of the diagram:

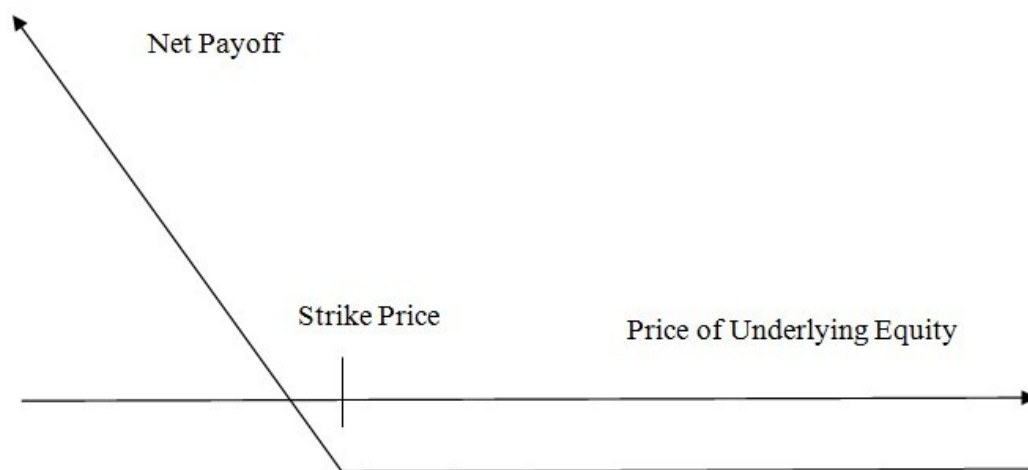


Observe here that the initial investment in the capital project is analogous to the strike price of the option whilst the costs associated with obtaining the right to implement the capital project at some future point in time (for example, the costs associated with a licence to prospect for oil or precious metals in a given area) are akin to the premium paid to acquire the option. In other words, the capital project will only be implemented under the condition that the present value of the future cash flows generated by the capital project exceeds the initial investment in the project. Likewise, holders of a financial call option will only exercise the option when the price of the underlying asset on which the option is written rises above the strike price of the option.

Under the NPV rule, value is calculated by determining the present value of the cash flows expected from the capital project using a discount rate that reflects the risks associated with the project. If the initial investment could be withdrawn cost-free and the future cash flows and discount rates were known with certainty, one could follow the simple NPV rule to make a straight forward investment decision as soon as the capital project avails itself to the firm. However, most investments are largely irreversible as the initial investment costs are sunk costs and the salvage value from withdrawing the investment would be significantly different from the initial investment costs. Moreover, cash flows and discount rates change over time

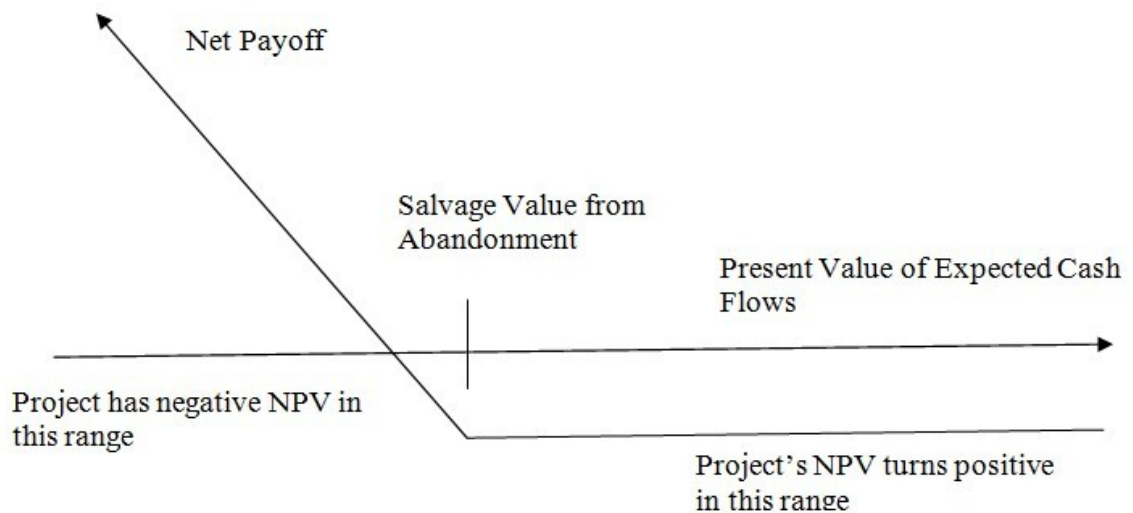
and so there is evolving uncertainty with general market conditions and the profitability of the products associated with the capital project. This will mean that the expected present value of the capital project will also change over time. This in turn means that the option to delay the capital project and allow the firm to wait until market conditions are favourably disposed towards the implementation of the project will have considerable value to the firm. In other words, firms which possess the option to delay their investment decisions will have a higher market value than identically equivalent firms which do not possess the option to delay their investment opportunities.

One can also compare a financial put option to the abandonment option a firm possesses; that is, the option to liquidate the firm's assets and distribute the proceeds to the firm's owners (net of any liabilities that must be discharged). Recall that a financial put option gives the buyer the right, but not the obligation, to sell the underlying asset at a predetermined price (the strike or the exercise price) prior to or on the expiration date of the option. The pay-off diagram for a financial put option can be illustrated as follows:



If the price of the underlying asset is less than the strike price, the owner will exercise the option and sell the stock at the strike price. The profit the owner of the option will earn is equal to the difference between the strike price and the sum of the price of the underlying asset and the premium paid for the option. Likewise, if

the expected present value of a firm's future cash flows is less than the liquidation value of the firm, the firm's owners could consider liquidating the firm. This will mean that the pay-off diagram for the abandonment option will be as follows:



The net pay-off from the abandonment option is the sum of the negative net present value that is avoided from now not having to continue to operate the capital project plus the salvage value obtained from liquidation of the capital project.

3.4 Real Option Theory and Valuation Models

The general ideas about the contribution that real options can make to the overall market value of a firm's equity discussed in the previous sections of this chapter are developed at a highly intuitive level. In this section, we summarise in detail how real option value has been included as an element of equity value in the models of Zhang (2000), Yee (2000) and Ashton et al. (2003). We also isolate the comparative strengths and weaknesses of each of these models.

3.4.1 Ashton, Cooke and Tippet (2003) Model

We begin our analysis with the Ashton et al. (2003) model of equity valuation. Here it will be recalled from equations (2.10) and (2.11) in Chapter 2 that the firm's instantaneous residual or abnormal earnings (per unit time) attributable to

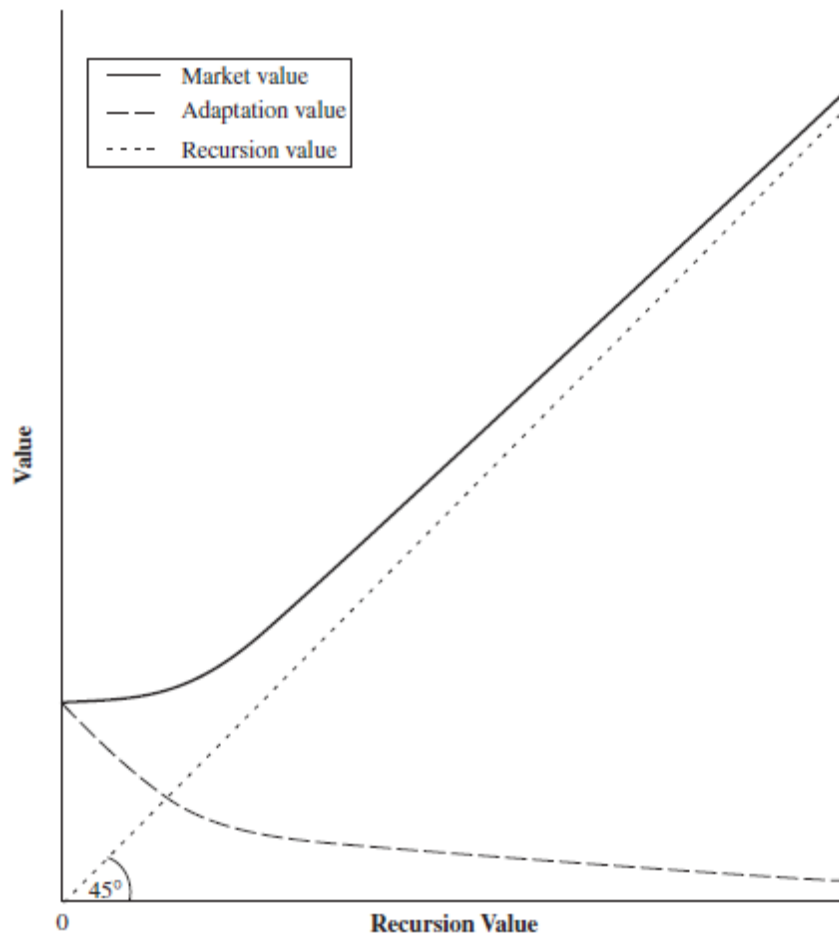
equity is defined as $a(t) = x(t) - ib(t)$, where i is the cost of equity (that is, the discount rate), $b(t)$ is the book value of equity and $x(t)$ is the earnings attributable to equity, all at time t . It then follows that the recursion value of equity, $\eta(t)$, can be stated in terms of the book value of equity plus the expected present value of the future abnormal earnings, or:

$$\eta(t) = b(t) + \int_t^{\infty} e^{-i(s-t)} E_t[a(s)] ds \quad (3.1)$$

where $E_t(\cdot)$ is the expectations operator taken at time t , based on the assumption that the firm is constrained to operate within its current investment opportunity set indefinitely into the future. We have also previously noted (as in section 2.6 of Chapter 2) that Burgstahler and Dichev (1997) identify a second component of equity value; namely, the adaptation value of equity. The adaptation component of equity value arises out of a firm's ability to change or modify its investment opportunity set; that is, to change or modify the way it uses its resources. Ashton et al. (2003) demonstrate the nature of the relationship between the market value of a firm's equity and its recursion and adaptation values in their Figure 1 (see below). The downward sloping curve represents the adaptation value of equity. The upward sloping line emanating from the origin represents the recursion value of equity. Note from equation (3.1), that when the present value of the expected abnormal earnings is a large negative figure relative to the book value of equity then the recursion value of equity will be close to zero. This in turn will mean that the market value of a firm's equity will be mainly comprised of adaptation value. When, however, the expected present value of future abnormal earnings is large relative to the book value of equity - that is, the firm is regarded as using its current resources in an efficient and effective way - then it is highly unlikely that the firm will want to change its existing investment opportunity set. This in turn will mean that the adaptation value of equity will be negligible and the market value of a firm's equity will be mainly comprised of recursion value. Figure 1 shows that in between these two extremes, the market value of equity consists of a more balanced combination of its recursion and adaptation values. Note in particular

how Figure 1 shows that there is a complementary relationship between the recursion and adaptation values of equity. When the recursion value of equity is relatively small then the adaptation value of equity will be relatively large and vice versa.

Figure 1
Relationship Between Adaptation Value, Recursion Value
and the Overall Market Value of Equity



Ashton et al. (2003) also show that the recursion value of equity is functionally proportional to its adaptation value. This has the important implication that once the recursion value of equity is known the adaptation value of equity can be determined and then the market value of equity as a whole can be determined.

We can start our development of the relationship between the market value of equity and earnings and book value by recalling from section 2.4 of Chapter 2 that Ohlson (1995) formulates the relationship between the book value of equity, $b(t)$, the abnormal earnings attributable to equity, $a(t)$, and the other information variable, $v(t)$, in terms of the first order vector system of stochastic differential equations:⁷

$$\begin{pmatrix} \frac{da(t)}{dt} \\ \frac{dv(t)}{dt} \end{pmatrix} = \begin{pmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{pmatrix} \begin{pmatrix} a(t) \\ v(t) \end{pmatrix} + \begin{pmatrix} k_1 & 0 \\ 0 & k_2 \end{pmatrix} \begin{pmatrix} \frac{dz_1(t)}{dt} \\ \frac{dz_2(t)}{dt} \end{pmatrix}$$

The elements, c_{11} , c_{12} , c_{21} and c_{22} , of the matrix $\begin{pmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{pmatrix}$ are structural coefficients which capture the sensitivity of increments in the variables comprising the firm's investment opportunity set to the existing levels of these variables.

Moreover, $k_1 = \frac{(i - c_{11})(i - c_{22}) - c_{21}c_{12}}{(i - c_{22})}$ and $k_2 = \frac{(i - c_{11})(i - c_{22}) - c_{21}c_{12}}{c_{12}}$ are

normalising constants. Finally, $\frac{dz_1(t)}{dt}$ and $\frac{dz_2(t)}{dt}$ are uncorrelated white noise processes with variance parameters of σ_1^2 and σ_2^2 , respectively.

A particular problem with the Ohlson (1995) linear information dynamics formulated above is that the recursion value of equity can in theory, fall below zero. This is an unrealistic assumption in most industrialised countries, as the liability of shareholders is limited to the original capital they contribute when the shares are first issued by the firm. Second, under the Ohlson (1995) linear information dynamics the variance associated with instantaneous increments in the recursion value of equity does not increase with the magnitude of recursion value. We have previously noted (as in section 2.4 of Chapter 2) how this runs counter to the commonly held belief that the variance associated with the increments of an economic variable must become larger as the variable grows in magnitude. To

⁷ Otherwise known as the Ohlson's linear information dynamics - as in equation (2.12) of Chapter 2.

adjust for these problems one can change the Ohlson (1995) linear information dynamics to the following specification (Davidson & Tippett, 2012, p. 209):

$$\begin{pmatrix} \frac{da(t)}{dt} \\ \frac{dv(t)}{dt} \end{pmatrix} = \begin{pmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{pmatrix} \begin{pmatrix} a(t) \\ v(t) \end{pmatrix} + \eta^\delta(t) \begin{pmatrix} k_1 & 0 \\ 0 & k_2 \end{pmatrix} \begin{pmatrix} \frac{dz_1(t)}{dt} \\ \frac{dz_2(t)}{dt} \end{pmatrix}$$

where $0 \leq \delta \leq \frac{1}{2}$ is a real number that ensures that the market value of the firm's equity remains finite as the recursion value approaches a limiting value of zero. Note how this parameter also incorporates the requirement that the variance associated with changes in the variables comprising the firm's investment opportunity set becomes larger as the recursion value of equity grows in magnitude. Ashton et al. (2003) set $\delta = \frac{1}{2}$, since this leads to a particularly tractable expression for the recursion value of equity. One can then follow procedures analogous to those surrounding equation (2.27) in section 2.4 of Chapter 2 and thereby show that the recursion value of equity evolves in terms of the following stochastic differential equation (Davidson & Tippett, 2012, pp. 217-218):

$$\frac{d\eta(t)}{dt} = (i\eta(t) - D(t)) + \sqrt{\eta(t)} \cdot \frac{dq(t)}{dt} \quad (3.2)$$

where $D(t)$ is the dividend payment (per unit time) made at time t , i is the cost of equity capital (again, on a per unit time basis) and $\frac{dq(t)}{dt} = \frac{dz_1(t)}{dt} + \frac{dz_2(t)}{dt}$ is a white noise process with variance parameter $\zeta^2 = \sigma_1^2 + \sigma_2^2$. This is the differential equation of a continuous time branching process. Branching processes arise in population dynamics, the term structure of interest rates and a number of other areas. Note how the above result implies that the increment in the recursion value of equity will have a mean of $E_t[d\eta(t)] = (i\eta(t) - D(t))dt$. This in turn will mean that larger dividend payments, $D(t)$, will lead to lower rates of growth in the recursion value of equity. Similar considerations show that the variance of the

increment in the recursion value of equity will have a variance of $\text{Var}_t[d\eta(t)] = \zeta^2 \eta(t) dt$. Note how this latter result encapsulates the requirement that the variance of increments in the recursion value of equity becomes larger as the recursion value itself grows in magnitude.

Our analysis to date focuses on only one component of market value of equity, namely, the recursion value of equity. We have previously noted, however, that there is a second element of equity value which is known as the adaptation value of equity. Ashton et al. (2003) present an aggregation theorem which shows that the recursion value of equity is functionally proportional to the adaptation value of equity. This means that the adaptation value of equity can be easily determined once the recursion value of equity is known. To determine the adaptation value of equity, we follow Davidson and Tippett (2012, p. 267) in defining $P(\eta(t))$ to be the market value of the firm's equity at time t in terms of its recursion value, $\eta(t)$. Moreover, from time t until time $(t + dt)$ the market value of the firm's equity will satisfy the “no arbitrage” condition:

$$P(\eta(t)) = D(t)dt + e^{-idt}E_t[P(\eta(t + dt))] \quad (3.3)$$

The “no arbitrage” condition means that the market value of equity at time t is equal to the expected market value of equity at time $(t + dt)$ discounted at the cost of capital, i , plus the dividend payment over the period from time t to time $(t + dt)$. One can then follow Davidson and Tippett (2012, pp. 267-268) in expanding $P(\eta(t + dt))$ as a Taylor's series about the point $\eta(t)$ and thereby show that the market value of equity will satisfy the following version of the Hamilton-Jacobi-Bellman equation:

$$\frac{1}{2}\zeta^2\eta\frac{d^2P}{d\eta^2} + [i\eta - D(t)]\frac{dP}{d\eta} + (D(t) - iP(\eta)) = 0 \quad (3.4)$$

Substitution shows $P_1(\eta) = \eta$, which represents the recursion value of equity, to be a solution to equation (3.4) and this will be so irrespective of the functional form of the dividend function, $D(t)$. This result is consistent with the Modigliani-Miller

Theorem that in a perfect capital market, the current market value of a firm's equity is independent of its future dividend policy. In other words, if a firm is constrained to operate indefinitely under its current investment opportunity set, then the present value of the future dividend payments is always equal to the present value of its future cash flows. However, Davidson and Tippett (2012, pp. 274-276) note that dividend payments reduce a firm's resources and thereby inhibit its ability to "ride out" difficult economic circumstances. It follows from this that a firm's dividend policy can have a significant impact on the adaptation value of its equity. A more intuitive way to think about how dividend payments impact on the real option value is that the value of a financial put option is an increasing function of expected dividend payments - that is, the real option is not dividend payout protected. One can illustrate the importance of this latter point by following Davidson and Tippett (2012, p. 268) in assuming that the firm makes dividend payments that are strictly proportional to the recursion value of equity; namely:

$$D(t) = \alpha\eta(t)$$

where $0 \leq \alpha < i$. Equation (3.4) can be then restated as follows:

$$\frac{1}{2}\sigma^2\eta\frac{d^2P}{d\eta^2} + (i - \alpha)\eta\frac{dP}{d\eta} + (\alpha\eta - iP(\eta)) = 0 \quad (3.5)$$

As previously noted, the recursion and adaptation values are complementary aspects of the market value of a firm's equity. Given this, we can follow Davidson and Tippett (2012, p. 269) in seeking a solution to the Hamilton-Jacobi-Bellman equation that takes the following form:

$$P(\eta) = \eta + Y(\eta) \quad (3.6)$$

where $Y(\eta)$ captures the adaptation value of the firm's equity. If one follows the procedures in Davidson and Tippett (2012, pp. 268-274), then it can be shown that the adaptation value of the firm's equity will be:

$$Y(\eta) = X(\eta) \int_{\eta}^{\infty} \frac{\exp[\frac{2(\alpha - i)y}{\zeta^2}]}{X^2(y)} dy$$

where :

$$X(\eta) = \sum_{j=0}^{\infty} a_j \eta^{j+1} = a_0 [\eta + \frac{\alpha}{\zeta^2} \eta^2 + \frac{\alpha(2\alpha - i)}{3\zeta^4} \eta^3 + \frac{\alpha(2\alpha - i)(3\alpha - 2i)}{18\zeta^6} \eta^4 + \dots]$$

and $a_0 = \frac{1}{P(0)}$. Here it can be shown that $P(0)$ is the adaptation value of the firm's equity when its recursion value falls away to nothing (Davidson & Tippett, 2012, pp. 273-274). Moreover, it then follows that the market value of the firm's equity will be:

$$P(\eta) = \eta + X(\eta) \int_{\eta}^{\infty} \frac{\exp[\frac{2(\alpha - i)y}{\zeta^2}]}{X^2(y)} dy \quad (3.7)$$

One can also show that when η goes off to infinity that $Y(\eta)$ declines towards zero; likewise when η falls to zero, $Y(\eta)$ approaches $\frac{1}{a_0}$, or equivalently, $P(0)$ (Davidson & Tippett, 2012, pp. 284-285). This in turn will mean that when the recursion value of the firm's equity is large - that is, when the current investment opportunity set is highly profitable - then the market value of the firm's equity is primarily determined by its recursion value η and the adaptation value of equity, $Y(\eta)$, is negligible. In this circumstance it is unlikely the firm will seek to change its current investment opportunity set. However, when the recursion value of equity is low - that is, when the current investment opportunity set is relatively unprofitable - the market value of equity is primarily determined by its adaptation value, $Y(\eta)$. In this circumstance investors will value a firm from the prospect of what other

valuable operations (options) are available to it rather than on the basis of its current operations.

Davidson and Tippett (2012, p. 221) show that when a firm does not pay dividends then the above equity valuation formula reduces to the following simpler expression:⁸

$$P(\eta) = \eta + \frac{P(0)}{2} \int_{-1}^1 \exp\left(\frac{-2\theta\eta}{1+z}\right) dz \quad (3.8)$$

Here $\theta = \frac{2i}{\zeta^2}$ is a measure of the relative stability with which the recursion value of equity grows over time (Ashton et al., 2003, p. 420).⁹ However, regardless of whether dividend payments occur or not, one can see from equation (3.7) and (3.8) that the market value of a firm's equity is a highly non-linear function of its determining variables. This mirrors the analogy we have already made in section 3.3 of this chapter between financial options and real options where we show that there is a highly non-linear relationship too between the market value of financial options and their determining variables.

3.4.2 Zhang (2000) Model

The Zhang (2000) equity valuation model is based on the assumption that firms can be classified into one of three categories. The first category is comprised of generally unprofitable firms with low operational efficiency. The second category is comprised of moderately profitable firms with modest operational efficiency.

⁸ An expression similar to this was first derived in the paper of Ashton et al. (2003).

⁹ Ataulah, et al., (2006, p. 255) provide empirical evidence relating to the U.K. economy which shows that the stability parameter varies from $\theta = 2.9619$ for the Information Technology, Non-Cyclical Consumer, Non-Cyclical Services and Resources industrial classification; to $\theta = 4.4787$ for the Basic Industries, General Industrials and Utilities industrial classification; to $\theta = 7.9737$ for the Cyclical Services Industrial classification; to $\theta = 8.3093$ for the Cyclical Consumer and Financials industrial classification.

The final group is comprised of highly profitable or growth firms with high operational efficiency. Zhang (2000, pp. 273-274) assumes that the operational

efficiency of the firm, $\tilde{\kappa}_{\tau+1} = \frac{\tilde{cr}_{\tau+1}}{as_{\tau}}$, evolves in terms of a pure random walk; namely:

$$\tilde{\kappa}_{\tau+1} = \kappa_{\tau} + \tilde{v}_{\tau+1} \quad (3.9)$$

where $\tilde{cr}_{\tau+1}$ is the operating cash flow the firm receives at time $(\tau + 1)$, as_{τ} is the “stock of assets” the firm has in place at time τ and $\tilde{v}_{\tau+1}$ is a zero mean random disturbance term. Zhang (2000) then modifies the Ohlson (1995) model by determining the value of equity in terms of the present value of the cash flows the firm expects to receive under its existing investment opportunity set plus a real option component that hinges on the firm’s operational efficiency. If the firm has low operational efficiency then the option to abandon the firm’s current investment opportunity set will make a significant contribution to the overall market value of the firm’s equity. This in turn will mean that there will be a highly non-linear relationship between the market value of a firm’s equity and its determining variables. If the firm exhibits steady-state efficiency then neither the abandonment option nor the growth option to expand the firm’s productive activities will make a significant contribution to the overall market value of the firm’s equity. This in turn will mean that there will be a broadly linear relationship between the market value of a firm’s equity and its determining variables; which is largely compatible with the Ohlson (1995) equity valuation model. Finally, if the firm has high operational efficiency then the growth option to expand the firm’s productive opportunities will make a significant contribution to the overall market value of equity. This will again mean that there will be a highly non-linear relationship between the market value of a firm’s equity and its determining variables.

Now, suppose one follows Zhang (2000, p. 274) in letting as_τ be the total stock of assets at time τ . It then follows that the total stock of assets will evolve in accordance with the following equation:

$$as_\tau = \gamma as_{\tau-1} + ci_\tau \quad (3.10)$$

or equivalently:

$$as_\tau = \sum_{s=0}^{\tau} \gamma^{\tau-s} ci_s \quad (3.11)$$

where ci_τ is the new capital investment at time τ and $0 \leq \gamma \leq 1$ is a “durability” measure. It then follows that if the firm invests $ci_0 = \$1$ in assets at time $\tau = 0$ then it will have a stock of assets amounting to $as_0 = \gamma as_{-1} + ci_0 = 1$. Similarly, the initial investment of $ci_0 = \$1$ will make a contribution to the stock of assets at time $\tau = 1$ of $as_1 = \gamma as_0 = \gamma$. Likewise, its contribution to the stock of assets at time $\tau = 2$ will be $as_2 = \gamma as_1 = \gamma^2$. Continuing with this process shows that its contribution to the stock of assets at time $n = 1, 2, 3, \dots$ will be $as_n = \gamma as_{n-1} = \gamma^n$. Now, we have previously noted how the firm’s cash flows from operations evolve in terms of the following process:

$$\tilde{cr}_{\tau+1} = \tilde{\kappa}_{\tau+1} \cdot as_\tau$$

Moreover, one can take expectations through equation (3.9) in which case we have:

$$E_\tau(\tilde{\kappa}_{\tau+n}) = \kappa_\tau$$

where $E_\tau(\cdot)$ is the expectations operator taken at time τ . It then follows that the expected cash flow from operations at time $(\tau + n)$ will be:

$$E_\tau(\tilde{cr}_{\tau+n}) = \tilde{\kappa}_\tau \cdot as_{\tau+n-1} = \tilde{\kappa}_\tau \gamma^{\tau+n-1}$$

One can then determine the internal rate of return, q_τ , associated with the above sequence of expected cash flows as follows:

$$0 = \sum_{n=1}^{\infty} \frac{\kappa_\tau \gamma^{n-1}}{(1 + q_\tau)^n} - 1 = \frac{\kappa_\tau}{1 + q_\tau - \gamma} - 1$$

This in turn will imply that:

$$q_\tau = \kappa_\tau - (1 - \gamma)$$

Zhang (2000, p. 276) then argues that in the steady-state efficiency classification the firm's economic earnings, $x_{\tau+1}^E$, under its existing investment opportunity set, will be given by:

$$x_{\tau+1}^E = q_{\tau+1} \cdot as_\tau = cr_{\tau+1} - ci_{\tau+1} = cr_{\tau+1} - (1 - \gamma)as_\tau$$

Recall here, in the steady-state efficiency classification that $as_{\tau+1} = as_\tau$ in which case it follows that $as_{\tau+1} = \gamma as_\tau + ci_{\tau+1} = \gamma as_{\tau+1} + ci_{\tau+1}$. It then follows that $as_{\tau+1} = \gamma as_{\tau+1} + ci_{\tau+1}$ or $ci_{\tau+1} = (1 - \gamma)as_\tau$ in which case we have $cr_{\tau+1} - ci_{\tau+1} = cr_{\tau+1} - (1 - \gamma)as_\tau$ as required.

At time $(t + 1)$ a firm will be confronted with one of three potential scenarios: (1) discontinuing its current operations; (2) continuing with its current investment opportunity set unaltered and (3) expanding its current operations. Zhang (2000, p. 276) shows that when the internal rate of return, q_t , is less than $(1 - \gamma c_d)(R - 1)$, where $0 < c_d < 1$, is the cost of discontinuation and R equals one plus the periodic risk-free rate of interest, then the firm should consider terminating its current operations. For firms with q_t larger than $(R - 1)$, expanding the current operating activities is considered as a preferable choice. When q_t lies between the internal rates of return of the above two scenarios, firms will choose to continue with their current investment opportunity sets unaltered.

One can then follow the procedures articulated in Zhang (2000, pp. 275-277) and thereby show that the market value of the firm's equity will be as follows:

$$V_t = \frac{x_t^E}{R - 1} + P_d(q_t).as_t + C_e(q_t).G \quad (3.12)$$

If the firm continues with its current operations at time $(t + 1)$, then its economic earnings will be $x_t^E = q_t.as_{t-1}$. Moreover, the market value of the firm's equity will

be $\frac{x_t^E}{R - 1}$. If in addition the firm has the option of abandoning its current operations at some future point in time of its own choosing then the market value of the firm's equity will be augmented by the value of the (put) option to discontinue its current operations; namely, $P_d(q_t).as_t$. Finally, if the firm also has the option of expanding its operations at some future point in time of its own choosing, then the market value of equity will also be augmented by the value of the (call) option to expand its operations, $C_e(q_t).G$, where G is a constant representing the "growth potential" from expansion.

The model discussed above relates equity value to the firm's current operational efficiency. However, in practice accounting information is used to measure a firm's operational efficiency. Given this, Zhang (2000) also develops an accounting-based valuation equation which relates equity value to the accounting or book variables appearing in a firm's financial statements. Here it will be recalled that under the clean surplus relation we have:

$$B_{t+1} = B_t - dep_{t+1} + ci_{t+1} \quad (3.13)$$

where B_t is the book value of assets at time t and dep_{t+1} is the depreciation expense for the period from time t until time $(t + 1)$. Zhang (2000, p. 277) follows Feltham and Ohlson (1996) in assuming that depreciation evolves in terms of the following equation:

$$\text{dep}_\tau = (1 - \delta) B_\tau, \quad (3.14)$$

where $0 < \delta < \gamma$ is a durability measure arising from the biases introduced by conservative accounting. Combining equations (3.13) and (3.14), it can be shown that:

$$B_{t+1} = \delta B_t + ci_{t+1}$$

which in turn means that

$$B_t = \sum_{s=0}^t \delta^{t-s} ci_s$$

Under conservative accounting, book value always underestimates the stock of assets in place; that is, the bias, u_t , of book value in measuring the stock of assets is always positive, or:

$$u_t = as_t - B_t > 0 \quad (3.15)$$

Now here we have previously noted that $as_\tau = \sum_{s=0}^{\tau} \gamma^{\tau-s} ci_s$ (as in equation 3.11) in

which case it can be shown that:

$$u_t = \sum_{s=0}^t (\gamma_{t-s} - \delta_{t-s}) ci_s$$

It thus follows that the change in the bias of the book value of assets over the period from time $(t - 1)$ until time t will be:

$$\Delta u_t \equiv u_t - u_{t-1} = \sum_{s=0}^t (\gamma^{t-s} - \delta^{t-s}) [ci_s - ci_{s-1}] + (\gamma^t - \delta^t) ci_0$$

Thus, under conservative accounting, the relation between the firm's economic earnings and its accounting earnings is $x_t^E = x_t + \Delta u_t$, where x_t is the accounting

earnings. It then follows that the bias associated with earnings from time $(t - 1)$ until time t will be equal to the change in the book value bias over the same period of time. One can then substitute the above expressions for $x_t^E = x_t - \Delta u_t$ as well as

$q_t = \frac{x_t^E}{as_{t-1}}$ and $u_t = as_t - B_t$ into equation (3.12) in which case the value of the

firm's equity can be stated in terms of the accounting (or book) variables appearing in the firm's financial statements (Zhang, 2000, pp. 275-279):

$$V_t = \frac{x_t^E}{R - 1} + P_d(q_t).as_t + C_e(q_t).G =$$

$$\frac{(x_t + \Delta u_t)}{R - 1} + P_d\left(\frac{x_t + \Delta u_t}{B_{t-1} + u_{t-1}}\right).(B_t + u_t) + C_e\left(\frac{x_t + \Delta u_t}{B_{t-1} + u_{t-1}}\right).G \quad (3.16)$$

We have previously noted how Zhang (2000) classifies firms into three categories: low-efficiency firms, steady-state firms and high-efficiency or growth firms. At date $(t + 1)$ steady-state firms are expected to continue operating under their existing investment opportunity sets in which case the market value of the firm's equity will be determined by the recursion value of its equity, $\frac{1}{R - 1}(x_t + \Delta u_t)$. In

contrast, there is a significant probability that in the immediate future low-efficiency firms will exercise the option they possess to abandon their current productive operations. It then follows that the market value of the firm's equity will be augmented by the value of the option to abandon its current operations,

$P_d\left(\frac{x_t + \Delta u_t}{B_{t-1} + u_{t-1}}\right).(B_t + u_t)$. Finally, in the immediate future the high-efficiency or

growth firms are more likely to exercise the option they possess to expand their operations. It then follows that the market value of equity will also be augmented

by the value of the option to expand the firm's operations, $C_e\left(\frac{x_t + \Delta u_t}{B_{t-1} + u_{t-1}}\right).G$.

There is a growing empirical literature which is compatible with the relationship between equity value and the accounting (or book) variables implied by the Zhang

(2000) equity valuation model. Zhang (2000, p. 283) predicts that for a given book value, equity value is convex in earnings for growth firms, where convexity arises from the growth (that is, call) options available to the firm. Here it will be recalled (as in section 2.6 of Chapter 2) that the test results in Burgstahler and Dichev (1997) are based on a step-wise linear model which regresses the market value to book value ratio against the earnings to book value ratio. This regression model shows that the average slope coefficients on the earnings to book value ratio for the group with high earnings are significantly larger than the coefficients for the group with moderate earnings. These results confirm the existence of convexity between the market value of a firm's equity and its earnings for growth firms and are compatible with the prediction of the Zhang (2000) equity valuation model. Zhang (2000, p. 283) also predicts that for a given book value, equity value is convex in earnings for low-efficiency firms where convexity arises from the abandonment (that is, put) options available to the firm. For steady-state firms which operate sufficiently well enough to neglect the liquidation options while lacking the potential to grow, Zhang (2000, p. 283) predicts that the market value of the firm's equity will be an approximately linear function of the earnings variable - in accordance with the predictions of the Ohlson (1995) model.

Zhang (2000, p. 286) also predicts that for a given earnings, equity value is convex in book value for low-efficiency and growth firms but approximately linear for steady-state firms. This in turn will mean that equity value increases with book value for low-efficiency firms and decreases with book value for high-efficiency or growth firms. Here it will be recalled that a second set of test results summarised in Burgstahler and Dichev (1997) are based on a step-wise linear model which regresses the market value to earnings ratio against the book value to earnings ratio. The results obtained from this regression procedure show that for high-efficiency firms (that is, firms with large earnings) the coefficients on the book value to earnings ratio are relatively low. In contrast, for low-efficiency firms (that is, firms with low earnings) the coefficients on the book value to earnings ratios are all relatively large. In between the low-efficiency and high-efficiency groups we have the steady-state efficiency firms for which there are only moderate coefficients on the book value to earnings ratios. In other words the coefficients on the book value

to earnings ratios for these steady-state firms generally fall between the ratios for the low-efficiency and high-efficiency groups of firms. These results confirm the existence of a convex relationship between the market value of a firm's equity and its book value and are compatible with the prediction of the Zhang (2000) model.

In addition, the Zhang (2000) model predicts that book value is a more important variable than earnings in explaining equity value for low efficiency firms. Here we would note that this prediction is consistent with the empirical results summarised in Collins et al. (1999) which are based on loss making firms only.¹⁰ The Collins et al. (1999) results show that the R^2 for a pure price-earnings regression is 9%. However, when book value is included as a component of the regression equation, the R^2 increases to 42%. Moreover, using data from the COMPUSTAT file Zhang and Chen (2002) test the empirical validity of Zhang (2000) model based on sample consisting of 55,387 firm-year observations covering the period from year 1981 to 1998. They classify the sample data into ten ordered but equally numerous groups based on the earning to book value ratio, q , which it is argued captures the efficiency with which the firm's assets are being utilised. They then run a regression for each group based on the following model (Zhang & Chen, 2002, p. 17):

$$V_i = \beta_0 + \beta_1 B_i + \beta_2 X_i + \mu_i \quad (3.17)$$

Here V_i is the market value of the i^{th} firm's equity, B_i is the corresponding book value of equity, X_i is the current period earnings and μ_i is a stochastic error term. The regression results, which are summarised in Table 3 (see below) of Zhang and Chen (2002, p. 36), show that as profitability, q , increases, the coefficients on the book value of equity, β_1 , decrease from 0.78 to -0.21 whereas the coefficients on earnings, β_2 , increase from -0.09 to 8.88. These results are consistent with the Zhang (2000) equity valuation model which emphasises that earnings will be the

¹⁰ See section 6 of Chapter 2 for a more detailed summary of the Collins et al. (1999) study.

principal determinant of equity value for high-efficiency firms whilst book value will be the principal determinant of equity value for low efficiency firms.

Table 3: Regressions of the market value of equity on earnings and book value by partitions of profitability^a

Partitions by profitability q	Obs.	Mean Profitability (\bar{q})	β_0	$t_{\beta 0}$	β_1	$t_{\beta 1}$	β_2	$t_{\beta 2}$	Adj. R^2
1	5,538	-0.11	3.83	22.62	0.78	45.37	-0.09	-0.55	0.35
2	5,538	0.02	3.41	18.29	0.83	60.38	0.43	1.07	0.47
3	5,538	0.06	4.13	20.20	0.60	19.32	4.61	9.05	0.51
4	5,539	0.09	4.98	21.36	0.74	15.81	2.53	4.71	0.52
5	5,539	0.12	6.92	28.64	0.49	10.75	4.51	10.70	0.53
6	5,539	0.14	7.36	28.00	0.51	10.22	4.62	11.75	0.54
7	5,539	0.16	8.22	30.11	0.42	7.20	5.02	12.31	0.52
8	5,539	0.19	9.91	32.72	0.07	1.13	7.11	17.51	0.46
9	5,539	0.23	10.89	34.75	-0.06	-0.79	8.12	19.84	0.44
10	5,539	0.33	11.60	32.41	-0.21	-2.95	8.88	29.24	0.37
Pooled	55,387	0.12	8.22	100.92	0.49	74.13	4.96	115.47	0.50

^a This table reports results from the following linear regression: $V_i = \beta_0 + \beta_1 B_i + \beta_2 X_i + \mu_i$.

Zhang and Chen (2002) also categorise their whole sample of 55,387 firm-years into four equally numerous groups of approximately 13,850 firm-years based on the growth potential of the firm. Two proxies are used to measure a firm's growth potential. The first is based on the market to book ratio for the firm's equity; in particular, larger market to book ratios are taken as indicative of higher growth potential than smaller market to book ratios. Second, growth potential is also measured in terms of the two year ahead growth rate in the book value of the firm's equity. Zhang and Chen (2002, p. 16) report that their empirical results are insensitive to which one of these two proxies is used to measure a firm's growth potential. The firm-years in each of the four groups are then ordered from the lowest to the highest efficiency level, q ; that is, in terms of the earnings to book value ratio. Each group is then divided into tertiles ($q1$, $q2$, $q3$) based on the ordered efficiency levels. Zhang and Chen's (2002) tests are, again, based on equation (3.17) for each tertile. The results are summarised in Panel B of Table 4 (see below) in Zhang and Chen (2002, p. 38). Note from this table how for the highest efficiency (that is $q3$) tertile groups, the coefficients, β_1 , associated with book value amounts to 0.15 for the lowest growth opportunity ($g1$) tertile group

(q3), 0.32 for the next to lowest growth opportunity (g2) tertile group (q3), 0.20 for the next to highest growth opportunity (g3) tertile group (q3) and finally, -0.22 for the highest growth opportunity (g4) tertile group (q3). These coefficients generally fall as the growth opportunity group increases from g1 to g4. In contrast, the coefficients, β_2 , on earnings for firms with high efficiency increase from 5.32 for the (g1-q3) group, to 5.68 for the (g2-q3) group to 7.60 for the (g3-q3) group and finally to 12.01 for the (g4-q3) group. The reader will be able to confirm from Panel B of Table 4 that similar results apply for the other efficiency groups. This confirms the Zhang (2000) model's prediction that book value becomes increasingly less important and the impact of earnings more pronounced in the equity valuation process as the growth opportunities available to the firm rise in magnitude.¹¹ The regression results summarised in Panel B of Table 4 also demonstrate that within each growth group, g, the coefficients on book value, β_1 , decrease as efficiency (q) increases and the coefficients on earnings, β_2 , increase as efficiency increases. These results are consistent with those summarised in Table 3,

¹¹ In the low efficiency range (q1), however, the coefficients, β_1 , on book value are on an increasing trend as growth opportunities increase. Zhang and Chen (2002) do not provide an explanation for this phenomenon. It seems that this scenario is outside the Zhang (2000) theoretical model. However, it cannot be ruled out in an empirical setting. As explained in Hao et al. (2008, p. 16), "the effect of investment growth is to increase the proportion of newly acquired assets relative to the old assets of a firm As the former are more adaptable and have higher exit value than the latter, the higher proportion of new assets increases the average percentage of investment values to be recovered, suggesting that growth increases the slope coefficient in the [market value and book value] relation in the low profitability region." The writer would make the observation that this phenomenon could also be caused by the heavy investment activities of newly started firms or financially non-distressed firms with significant adaptability options whose market value hinges largely upon their growth potential (book value and other financial or non-financial information, etc.) rather than their negligible or even negative net cash flows (earnings) at the beginning of their business or from their operations. For example, the market value of internet firms is, to a great extent, supported by taking favourable market positions and taking advantage of unrevealed future investment opportunities (Yee, 2000, p. 229). In this case, when growth increases, the coefficients on book value increase for firms with low profitability.

and again, indicate that the value effect of book value and earnings varies in accordance with a firm's efficiency, q .

Panel B: Regression results using the ex ante measure of growth opportunity g (3-digit SIC industry median market to book ratio)^a

Partition by growth g	Partition by profitability q	β_0	t_{β_0}	β_1	t_{β_1}	β_2	t_{β_2}	Adj. R^2
Lowest $g1$	Lowest $q1$	2.86	13.92	0.77	61.63	1.18	9.35	0.55
	$q2$	6.88	25.75	0.47	15.86	3.52	14.48	0.51
	Highest $q3$	9.39	26.52	0.15	3.48	5.32	19.94	0.41
$g2$	Lowest $q1$	3.20	15.98	0.84	62.34	0.85	6.17	0.53
	$q2$	5.85	24.31	0.48	13.96	5.25	18.40	0.59
	Highest $q3$	9.52	27.96	0.32	6.12	5.68	18.84	0.45
$g3$	Lowest $q1$	3.48	18.06	0.87	63.22	1.00	7.11	0.53
	$q2$	5.78	20.43	0.50	9.75	6.01	13.94	0.57
	Highest $q3$	9.86	31.10	0.20	3.40	7.60	22.80	0.47
Highest $g4$	Lowest $q1$	4.79	21.32	1.00	53.37	-0.12	-0.66	0.45
	$q2$	6.63	22.72	0.45	7.94	7.21	15.27	0.59
	Highest $q3$	9.30	28.72	-0.22	-3.59	12.01	38.23	0.55

^a This panel reports results from the following linear regression: $V_i = \beta_0 + \beta_1 B_i + \beta_2 X_i + \varepsilon_i$.

Ghosh et al. (2005) empirically test the relationship between the market value of equity and its determining variables. Their results are based on all firm-years from 1980 to 2000 taken from COMPUSTAT file. They show that for firms with at least five consecutive years of earnings growth, the coefficient on earnings is highly positive and significant while the coefficient on book value is significantly negative. Firms with five consecutive years of earnings growth are perceived to have significantly more growth options than other firms. This result implies that as a firm's growth opportunities become more sustainable, the valuation weight carried by earnings becomes larger and the valuation weight on book value become smaller. This is again consistent with the Zhang (2000) model's prediction that when firms are characterised by significant growth potential, book value will play only a minor role in the determination of their equity values.

Although the empirical evidence is broadly compatible with the Zhang (2000) model, it nonetheless needs to be emphasised that it has some significant limitations which have not previously been identified. We begin by noting that Zhang (2000 pp. 273-274) assumes that the firm's operating efficiency evolves in terms of a pure random walk (as in equation 3.9 above). This in turn will mean that

increments in the firm's operating efficiency will have a mean of zero and an inter-temporally constant variance. However, this assumption runs counter to the commonly held belief that the variance associated with the increments in an economic variable will become larger as the economic variable grows in magnitude (as with the Ashton et al. (2003) model summarised above). The second downside of the Zhang (2000) model is that it is developed in discrete time. Here Cox and Miller (1965, p. 146) note that:

“... discrete time models are usually easier for numerical analysis, whereas simple analytical solutions are more likely to emerge in continuous time.”

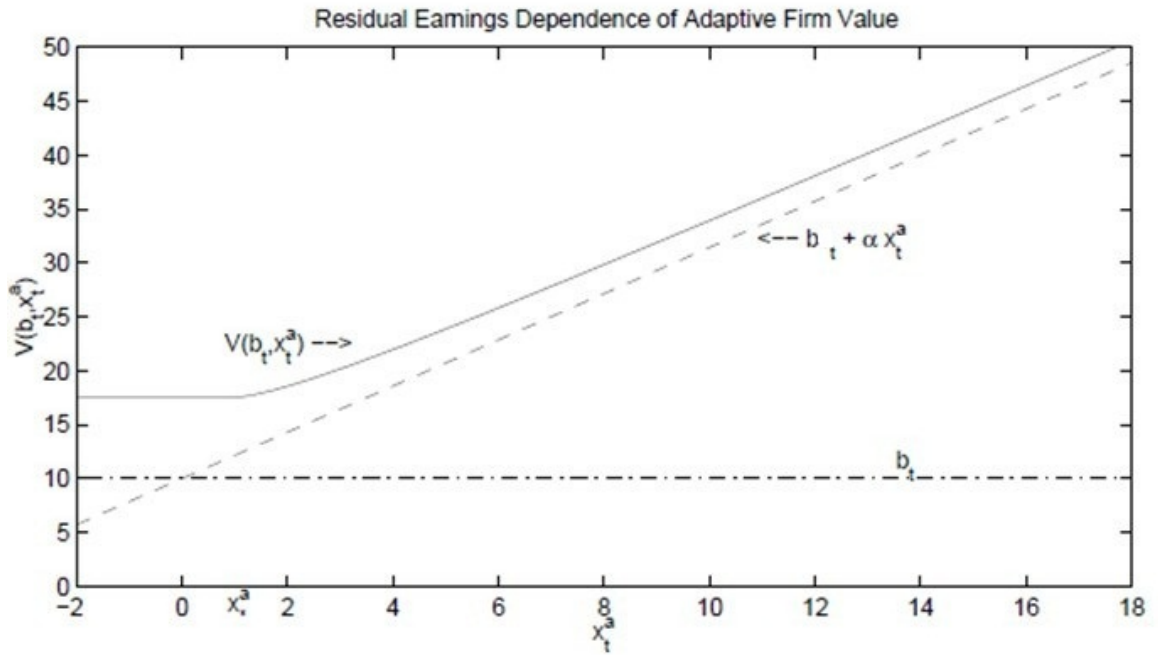
Likewise, Karlin and Taylor (1981, p. 356) observe that:

“...a great advantage in the use of continuous stochastic differential equations versus discrete models . . . is that explicit answers are frequently accessible in the continuous formulations. The dependence and sensitivity of the process on the parameters are therefore more easily discernible and interpretable [with continuous time models].”

Given this, it is not surprising that Zhang (2000) is unable to provide a closed form solution for either the abandonment option or the growth option values in his model. This in turn makes it difficult to assess the distributional properties of the equity values implied by his model. Third, the Zhang (2000) equity valuation model is difficult to implement empirically. The model provides no concrete guidance, for example, about when it will be optimal for the firm to exercise its abandonment and growth options. It is for this reason that the empirical implementation of the Zhang (2000) model is invariably based on piece-wise linear approximations of the relationship between the market value of equity and its determining variables.

3.4.3 Yee (2000) Model

We have previously noted that the empirical evidence documented in Burgstahler and Dichev (1997), Barth et al. (1998) and others shows that there is a complementary relationship between a firm's earnings and the book value of its equity; that is, when the valuation coefficient associated with book value is "large" then the valuation coefficient associated with earnings will be "small" and vice versa. This in turn will mean that there is a convex relationship between the market value of a firm's equity, its book value and its earnings. Yee (2000) argues that a firm's ability to adapt its productive operations combined with a Markovian accounting system and the Modigliani-Miller dividend irrelevance theorem will lead to *convexity* between the market value of a firm's equity, its earnings and its book value and *complementarity* as to the relative importance of the balance sheet and the income statement in equity valuation. He also argues that the price valuation equation is necessarily non-linear and that non-linearity is evidently traced to the value of the adaptation options a firm possesses. Yee (2000) is amongst the first to provide a theoretical basis for this complementarity relationship. He does this by considering a simple model under which a firm periodically acquires a single capital project whose abnormal earnings (or equivalently, its residual income) in the first year of its operations is drawn from a uniform distribution with compact support. After the first year, the capital project's abnormal earnings decay away in an exponential and deterministic (or known) fashion until (at one of a countably infinite number of points in time) the firm abandons the capital project in favour of a potentially, more profitable capital project. This latter capital project will also have a residual income in the first year of its operations which is drawn from the uniform distribution previously referred to. Yee (2000) then uses the clean surplus requirement in conjunction with a discrete time dynamic programming algorithm similar to that employed by Ashton et al. (2003) to show that the overall market value of the firm's equity can be summarised in terms of the following diagram (Yee, 2000, p. 236):



Here b_t is the book value of the firm's equity, x_t^a is the abnormal earnings associated with the single capital project implemented by the firm (both at time t), α is the Ohlson (1995) valuation coefficient associated with the firm's abnormal earnings and $V(b_t, x_t^a)$ is the overall market value of the firm's equity. Yee (2000, p. 231) notes that $(b_t + \alpha x_t^a)$ is the Ohlson (1995) value of the firm's equity (that is, the recursion value of equity) in which case it follows that $V(b_t, x_t^a) - (b_t + \alpha x_t^a)$ will be the real (adaptation) option value of equity at any given point in time, t . Yee (2000) also observes how the above diagram implies that the adaptation value of equity is a convex decreasing function of the capital project's abnormal earnings. In other words, adaptation value gradually decays away as the abnormal earnings variable grows in magnitude so that in the limit, the market value of the firm's equity is given by its Ohlson (1995) value; or:

$$\lim_{x_t^a \rightarrow \infty} V(b_t, x_t^a) = (b_t + \alpha x_t^a)$$

This result is also obtained by Ashton et al. (2003) (as summarised at the beginning of this section) for a much more sophisticated supply side model of the firm. However, Ashton et al. (2003) also show that near the origin (where the recursion value of equity is relatively small) that the overall market value of equity, $V(b_t, x_t^a)$, will at first decline before eventually turning upwards as the abnormal earnings variable, x_t^a , grows in magnitude. This is a property which Burgstahler and Dichev (1997, p. 205) and Ashton et al. (2003, p. 430) amongst others show is borne out by the empirical evidence. However, as one can see from the above Figure, it appears to be absent from the Yee (2000) model. We would conclude by emphasising that the Yee (2000) model is formulated in discrete time and therefore like the Zhang (2000) model, is unable to provide a closed form solution for either the adaptation value or overall market value of the firm's equity.

3.4.4 Conclusion

In this section, we have discussed three representative non-linear equity valuation models in the extant literature; namely, the Ashton et al. (2003) model, the Zhang (2000) model and the Yee (2000) model. All three models are compatible with the empirical evidence which shows that the market value of a firm's equity is in a non-linear relationship with its determining variables. In particular, adaptation value will normally comprise a significant proportion of the overall market value of the firm's equity. The models also imply that there is a complementary relationship between the valuation coefficients associated with a firm's earnings and the book value of its equity. However, we need to emphasise that the Ashton et al. (2003) model has a marked advantage over both the Zhang (2000) and Yee (2000) models since it is developed in continuous time and therefore provides a closed form solution for the adaptation value and overall market value of a firm's equity. This is probably the most important reason behind our desire to use the Ashton et al. (2003) equity valuation model as the basis for the empirical tests conducted in this dissertation. We will discuss the Ashton et al. (2003) model and its further development in much greater detail in Chapter 5.

3.5 Momentum, Acceleration and the Valuation of Equity

We have previously noted how linear equity valuation models do not fully capture the relationships which exist between earnings, the book value of a firm's equity and the overall market value of its equity and nor can they capture the non-linearities that arise from the adaptation options that are generally available to firms. This will mean that the linear valuation models which dominate the empirical research of the area will almost certainly be affected by an omitted variables problem. It is well known that omitted variables will create biases as the model compensates for the missing variables by over or underestimating one or more of the parameters associated with the variables that are included in the regression model. It thus follows that the coefficients associated with the earnings and book value variables generated by the linear equity valuation models will be unreliable and problematic. In this section, we will discuss other possible omitted factors; in particular, the momentum and acceleration of the variables comprising a firm's investment opportunity set. We will show that these momentum and acceleration factors can also have a significant impact on the market value of a firm's equity. At the end of this section we also consider the impact that stochastic variations in adaptation value can have on the market value of a firm's equity.

We begin our consideration of these issues by recalling from section 2.3 of Chapter 2 how in the Ohlson (1995) model the abnormal earnings, $a(t)$, and information variable, $v(t)$, evolve in terms of a first order vector system of stochastic differential equations - the so called Ohlson (1995) linear information dynamics. However, the empirical evidence summarised in section 2.5 of Chapter 2 shows that valuation models based on first order processes generally under-estimate equity values. In particular, recent empirical evidence shows that the momentum (and possibly acceleration) of the accounting variables comprising a firm's investment opportunity set may have a significant impact on the market value of its equity (Chordia & Shivakumar, 2006). Hong et al. (2003) also find that following an earnings momentum investment strategy in stock markets in Australia, Canada, France, Germany, Hong Kong and United Kingdom generates significant positive average abnormal returns. Given this, Davidson and Tippett (2012, pp. 286-298)

incorporate the momentum and acceleration effects of accounting variables into the Ashton et al. (2003) equity valuation model. They do so by re-stating the firm's investment opportunity set in terms of a second and possibly higher order system of stochastic differential equations. The Davidson and Tippett (2012) model thus provides a theoretical basis for the emerging empirical literature that documents a strong relationship between the momentum of the accounting variables comprising a firm's investment opportunity set and the market value of its equity.

One can accommodate momentum in the determining variables by stating the firm's investment opportunity set in terms of the following reduced form vector system of second order stochastic differential equations (Davidson & Tippett, 2012, pp. 288-292):

$$\begin{pmatrix} \frac{d^2a(t)}{dt^2} \\ \frac{d^2v(t)}{dt^2} \end{pmatrix} = \begin{pmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{pmatrix} \begin{pmatrix} a(t) \\ v(t) \end{pmatrix} + \sqrt{\eta(s)} \begin{pmatrix} k_1 & 0 \\ 0 & k_2 \end{pmatrix} \begin{pmatrix} \frac{dz_1(t)}{dt} \\ \frac{dz_2(t)}{dt} \end{pmatrix} \quad (3.18)$$

Here it will be recalled that $a(t)$ is the instantaneous abnormal earnings attributable to equity and $v(t)$ is the other information variable that captures information relevant to the value of the firm's equity but which has not, as yet, been incorporated into the firm's accounting records. Moreover, $\eta(t)$ is the recursion value of equity, $\frac{d^2a(t)}{dt^2}$ is the acceleration (per unit time) in the abnormal earnings

and $\frac{d^2v(t)}{dt^2}$ is the acceleration (per unit time) in the other information variable. The

acceleration in the firm's abnormal earnings and the information variable captures the rate of change in the momentum of these two variables. The c_{11} , c_{12} , c_{21} and

c_{22} are structural coefficients, $k_1 = \frac{(i^2 - c_{11})(i^2 - c_{22}) - c_{21}c_{12}}{(i^2 - c_{22})}$

and $k_2 = \frac{(i^2 - c_{11})(i^2 - c_{22}) - c_{21}c_{12}}{c_{12}}$ are normalising constants and i is the cost of the

firm's equity capital. Finally, $\frac{dz_1(t)}{dt}$ and $\frac{dz_2(t)}{dt}$ are white noise processes with variance parameters of σ_1^2 and σ_2^2 respectively. Note also that the stochastic component in the above equation hinges on the recursion value of equity, $\eta(t)$. This assumption reflects the commonly held belief that the uncertainty associated with increments in an economic variable - in this instance abnormal earnings - become more pronounced as the affected variable grows in magnitude.

One can use this specification of the investment opportunity set in conjunction with procedures similar to those employed with the Ohlson (1995) model in section 2.4 of Chapter 2 and thereby show that the recursion value of a firm's equity, $\eta(t)$, will be (Davidson & Tippett, 2012, p. 293):

$$\eta(t) = b(t) + \frac{i(i^2 - c_{22})a(t) + (i^2 - c_{22})a'(t) + ic_{12}v(t) + c_{12}v'(t)}{(i^2 - c_{11})(i^2 - c_{22}) - c_{12}c_{21}} \quad (3.19)$$

Here $a'(t)$ is the momentum in the firm's earnings and $v'(t)$ is the momentum in the information variable. The market value of the firm's equity is still determined by equation (3.7) whereas the expression for $\eta(t)$ is determined by equation (3.18) instead of equation (2.22) as summarised in section 2.4 of Chapter 2. Note also that the momentum in the firm's earnings and the momentum in the other information variable are measured by their first derivatives, $a'(t)$ and $v'(t)$, respectively. More important, however, is that $a'(t)$ and $v'(t)$ can have a significant determining influence on the recursion value of a firm's equity and hence, the market value of equity as a whole. The bigger the momentum associated with earnings and the other information variable, the bigger the market value of a firm's equity.

Davidson and Tippett (2012) also show that it is not only the momentum of variables comprising a firm's investment opportunity set which can have a significant impact on recursion value but their acceleration and even higher derivatives as well. They demonstrate this by incorporating the momentum and acceleration of variables comprising a firm's investment opportunity set into the

equity valuation process by stating the firm's investment opportunity set in terms of the following reduced form vector system of third order stochastic differential equations (Davidson & Tippett, 2012, pp. 295-297):

$$\begin{pmatrix} \frac{d^3 a(t)}{dt^3} \\ \frac{d^3 v(t)}{dt^3} \end{pmatrix} = \begin{pmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{pmatrix} \begin{pmatrix} a(t) \\ v(t) \end{pmatrix} + \sqrt{\eta(s)} \begin{pmatrix} k_1 & 0 \\ 0 & k_2 \end{pmatrix} \begin{pmatrix} \frac{dz_1(t)}{dt} \\ \frac{dz_2(t)}{dt} \end{pmatrix}$$

Here $\frac{d^3 a(t)}{dt^3}$ is the jerk (per unit time) in the abnormal earnings and $\frac{d^3 v(t)}{dt^3}$ is the

jerk (per unit time) in the information variable. The jerk of a firm's abnormal earnings and information variable captures the rate of change in the acceleration of

the variables. Moreover, $k_1 = \frac{(i^3 - c_{11})(i^3 - c_{22}) - c_{21}c_{12}}{(i^3 - c_{22})}$ and

$k_2 = \frac{(i^3 - c_{11})(i^3 - c_{22}) - c_{21}c_{12}}{c_{12}}$ are normalising constants. All other parameters are

as previously defined.

One can again use this specification of the investment opportunity set in conjunction with procedures similar to those employed with the Ohlson (1995) model to show that the recursion value of a firm's equity, $\eta(t)$, will be (Davidson & Tippett, 2012, pp. 295-298):

$$\eta(t) = b(t) + \frac{i^2(i^3 - c_{22})a(t) + i(i^3 - c_{22})a'(t) + (i^3 - c_{22})a''(t) + i^2c_{12}v(t) + ic_{12}v'(t) + c_{12}v''(t)}{(i^3 - c_{11})(i^3 - c_{22}) - c_{12}c_{21}} \quad (3.20)$$

where $a'(t)$ is the momentum in the firm's earnings and $v'(t)$ is the momentum in the other information variable; $a''(t)$ is the acceleration in the firm's earnings and $v''(t)$ is the acceleration in the firm's other information variable. Under this specification the market value of the firm's equity is still determined by equation

(3.7) except that we now use equation (3.20) as the expression for the recursion value of equity, $\eta(t)$, instead of expression for the recursion value of equity defined by equation (2.22) in section 2.4 of Chapter 2 or equation (3.18) above. Note that the momentum in the firm's earnings and the other information variable and the acceleration in the firm's earnings and the other information variable are measured by their first derivatives and second derivatives, respectively. More important, however, is that, $a'(t)$, $v'(t)$, $a''(t)$ and $v''(t)$ can have a significant determining influence on the recursion value of a firm's equity and hence by implication, the market value of equity as well. The bigger the momentum and acceleration associated with earnings and the other information variable, the bigger the recursion value and market value of the firm's equity.

Davidson and Tippett (2012, p. 298) go on to emphasise that the above analysis may be generalised by allowing a firm's investment opportunity set to be comprised of an even higher order system of stochastic differential equations. If, for example, a firm's investment opportunity set is characterised by a fourth order system of stochastic differential equations, it can then be shown that in addition to the momentum (first derivative) and acceleration (second derivative) of the determining variables, the jerk (or third derivative) of the determining variables can also have a significant impact on the recursion value of a firm's equity. Likewise, the snap (fourth derivative), crackle (fifth derivative) and pop (sixth derivative) of the variables comprising a firm's investment opportunity set can also have a significant impact on both the recursion and overall market value of a firm's equity. Moreover, the omission of these variables (that is, momentum, acceleration, snap, crack, pop, etc.) from the linear valuation models which pervade this area of the empirical literature will also mean that the estimated valuation parameters associated with a firm's book value and its earnings will be biased by virtue of the omitted variables theorem.

The results obtained above provide us with a method for determining the intrinsic (or fundamental) value of an equity security when the firm is indefinitely constrained to operate within its existing investment opportunity set. However, in practice firms invariably have the ability to change their investment opportunity

sets - particularly so when the profits from their current operations decline to a permanently low level. A firm's ability to change its existing investment opportunity set gives rise to a second component of equity value; namely, the adaptation value of equity. Our earlier analysis (as with equation (3.7) in section 3.4 of this chapter) assumed that if the recursion value of equity falls to zero, then the firm will be able to exchange its current investment opportunity set for a suite of assets having an inter-temporally known and constant adaptation value. However, it is highly likely that the adaptation value of equity will evolve stochastically through time rather than being an inter-temporally constant figure as previously assumed. Davidson and Tippett, (2012, p. 298) address this problem by supposing that the adaptation value of equity evolves in terms of the following "technological uncertainty" process:

$$\frac{dB(t)}{dt} = \lambda B(t) + B(t)\sqrt{\eta(t)} \cdot \frac{dg(t)}{dt}$$

where $B(t)$ is the adaptation value (conditional on the recursion value of the firm's equity falling away to nothing), $E_t[\frac{dB(t)}{B(t)}] = \lambda dt$ is the expected instantaneous rate of growth in the adaptation value of equity and $\frac{dg(t)}{dt}$ is a white noise process with variance parameter δ^2 . Moreover, one would expect λ to be less than the cost of capital, i , since the payment of dividends will reduce the adaptation value of equity in a similar way to that in which dividend payments reduce the recursion value of equity (see section 2.4 of Chapter 2). Finally, the variance of instantaneous proportionate changes in adaptation value turns out to be (Davidson & Tippett, 2012, pp. 298-299):

$$\text{Var}_t[\frac{dB(t)}{B(t)}] = \delta^2 \eta(t) dt. \quad (3.21)$$

Note how this latter equation shows that the uncertainty associated with the rate of growth in adaptation value is a strictly increasing function of recursion value, $\eta(t)$. This reflects the fact that when recursion value is relatively large the firm will be less likely to adapt its investment opportunity set to alternative uses. However,

when the recursion value falls away to nothing, all uncertainty associated with the adaptation value of equity is resolved. In this circumstance the firm will exchange its current investment opportunity set for the alternative opportunities reflected in the current adaptation value of equity, $B(t)$.

Now here it will be recalled (as in section 2.6 of Chapter 2) that the market value of the firm's equity is the sum of its recursion value and its adaptation value. Given this, suppose we follow previous analysis (as in section 3.4 above) in assuming that the dividend payments made by a firm are strictly proportional to the recursion value of its equity; that is, $D(t) = \alpha\eta(t)$, where $0 \leq \alpha < i$ is the constant of proportionality. Then one can follow Davidson and Tippett (2012, pp. 298-301) in using this assumption in conjunction with the absence of arbitrage opportunities and thereby show that the market value of the firm's equity will be:

$$P(B, \eta) = \eta + BX(\eta) \int_{\eta}^{\infty} \frac{e^{-\varphi y}}{X^2(y)} dy \quad (3.22)$$

where:

$$X(\eta) = \eta + \sum_{j=1}^{\infty} \frac{2^j((\alpha - \rho\zeta\delta) + \lambda)(2(\alpha - \rho\zeta\delta) - (i - \lambda)) \cdot \dots \cdot (j(\alpha - \rho\zeta\delta) - ((j-1)i - \lambda))}{j!(j+1)!\zeta^{2j}} \cdot \eta^{j+1}$$

Here, ρ is the correlation coefficient between instantaneous changes in the adaptation value of equity and the recursion value of equity; ζ^2 is the variance parameter associated with the white noise process which characterises the evolution of the recursion value of equity and $\varphi = \frac{2(i + \rho\zeta\delta - \alpha)}{\zeta^2} > 0$ is a risk parameter. Here we would emphasise that equation (3.22) satisfies the boundary conditions $P(B, 0) = B$ and $\lim_{\eta \rightarrow \infty} P(B, \eta) = \eta$. The first boundary condition

captures the requirement that if the recursion value of equity falls away to nothing then the firm will be able to exchange its current investment opportunity set for a suite of assets with an adaptation value of B . The second boundary condition captures the requirement that when the firm's current investment opportunity set is highly profitable then the adaptation value of equity will be negligible. The market value of equity will then be mainly comprised of its recursion value. Equation (3.22) again shows that there is a non-linear and highly convex relationship between the market value of the firm's equity and its determining variables.

3.6 Conclusion

In recent years there has been a substantial volume of research devoted to the problem of determining the intrinsic (or fundamental) value of equity in terms of the information appearing in a firm's financial statements (earnings, book value of equity, etc.) as well as other industry specific and macroeconomic factors. The conventional approach determines intrinsic value on the assumption that the firm is indefinitely constrained to operate within its existing investment opportunity set. This in turn will imply that there is a purely linear relationship between the market value of a firm's equity and its determining variables. However, recently compelling empirical evidence has emerged that shows there is a highly non-linear and generally convex relationship between the market value of a firm's equity and the information appearing in its financial statements. Moreover, developments in equity valuation theory show that the non-linear relationships are caused by the strategic and operational (adaptation) options that firms possess to modify or even abandon their current investment opportunity sets.

Intuitively, it is not hard to understand how adaptation options have an important role to play in the determination of the market value of a firm's equity. For example, growth options which are analogous to financial call options, enable a firm to have the right, but not the obligation to implement a new capital project; whilst abandonment options which are analogous to financial put options, give a firm the right, but not the obligation to liquidate the firm's existing operations. It is likely that both these options will have considerable value to the firm at various

stages in its development. For example, the growth option will be highly valued when the firm is highly profitable whilst the abandonment option will have considerable value should the firm fall on hard times. Given this, in this chapter we have summarised the various theoretical frameworks which have been suggested in the literature for valuing equity when firms possess the real options which will enable them to change their investment opportunity sets. In particular, three exemplar option-style models - namely, the Ashton et al. (2003) model, the Zhang (2000) model and the Yee (2000) model - have been discussed in detail in this chapter. These models re-examine the role that earnings, book value and other determining variables play in the equity valuation process and capture both the recursion value and the adaptation value components of the market value of a firm's equity. They thereby provide a more complete theoretical framework for the equity valuation process than the purely linear technologies which effectively deny the existence of the adaptation options which are available to firms. Though all three models are compatible with the empirical evidence in the sense that they all predict that there will be a highly non-linear and convex relationship between the market value of a firm's equity and its determining variables only the Ashton et al. (2003) model is developed in continuous time and therefore provides a closed form solution for the adaptation and overall market value of a firm's equity.

At the end of this chapter, we also discussed the Davidson and Tippett (2012) model which develops the Ashton et al. (2003) equity valuation model in terms of a higher order system of stochastic differential equations that incorporate the momentum (first derivative) and acceleration (second derivative) of the determining variables which appear in the firm's investment opportunity set. It has been shown that the higher order derivatives of the determining variables can also have a significant impact on the recursion value of equity and hence, on the overall market value of a firm's equity. Moreover, the Davidson and Tippett (2012) model allows adaptation value to evolve stochastically through time instead of using an inter-temporally known and constant adaptation value as assumed by Ashton et al. (2003), Burgstahler and Dichev (1997) and virtually all other models in the area.

In Chapter 4 and Chapter 5, we implement our empirical analysis of the equity securities listed on the Shanghai Stock Exchange over the period from 1999 until 2012. In particular, in Chapter 4 we will assess whether there is a relationship between a firm's earnings momentum (and acceleration) and the market value of its equity. The methodology used in Chapter 4 will be based upon Davidson and Tippett (2012) model which develops the Ashton et al. (2003) equity valuation model in terms of a higher order system of stochastic differential equations that reflects the impact of the momentum (first derivative) and acceleration (second derivative) of the variables comprising the firm's investment opportunity set on the market value of equity. Then in Chapter 5 we will go on to employ both linear and non-linear methodologies to estimate the relationships which exists between the market value of equity and its determining variables for stocks listed on the Shanghai Stock Exchange. The methodological approaches used in Chapter 5 will hinge in particular on the Ashton et al. (2003) model since as previously noted, it provides a closed form solution for the market value of a firm's equity in terms of its determining variables.

Chapter 4

Methodology and Empirical Analysis on Earnings Momentum and Earnings Acceleration

4.1 Introduction

This chapter is the first of two chapters that summarise the empirical results relating to the various equity valuation models outlined in the preceding chapters. Our data set consists of a large sample of firms listed on the Shanghai Stock Exchange (SSE). In particular, this chapter provides part of the main empirical results of this dissertation and aims to report whether earnings momentum and earnings acceleration have any impact on the market value of equity for firms listed on the SSE. Here we would note that there is a voluminous literature which has investigated the relationship between earnings momentum and price momentum. This literature generally concludes that there is an inconsistent and often inconclusive relationship between earnings momentum and price momentum across international financial markets. For example, a significant and positive correlation between earnings momentum and price momentum has been found in some countries (Australia, UK, Canada, etc.); whilst no statistically reliable evidence of a relationship between these variables has been found in other countries (Japan, Korea, Malaysia, Singapore, etc.) (Hong et al., 2003). To the best of the writer's knowledge, however, no previous study has investigated and measured the impact of earnings momentum (and earnings acceleration) on the market value of a firm's equity itself rather than on the price momentum of its equity stock. Nonetheless, recent developments in equity valuation theory (Davidson & Tippett, 2012) show that the momentum and acceleration of variables comprising the firm's investment opportunity set can have significant impact on the market value of its equity. Given this, the purpose of this chapter is to examine the relationship between earnings momentum and earnings acceleration and the market value of equity. The empirical work summarised in this chapter is, as far as I am aware, the

first to test the value impact of earnings momentum and earnings acceleration to the market value of a firm's equity, and particularly for firms listed on the SSE.

The remainder of this chapter is organised as follows: section 4.2 summarises the essential characteristics of the benchmark model on which our empirical analysis is based; namely, the Davidson and Tippett (2012) model and summarises the way in which we empirically implement the model. Section 4.3 is comprised of two main parts. In each part, we first explain how we select the data upon which our empirical analysis is based and define the variables used in our empirical analysis. We then provide basic descriptive statistics pertaining to our data and summarise our empirical results. Moreover, in each part we also classify firms into low-efficiency, steady-state and high-efficiency groups and re-estimate the parameters generated by the benchmark model in order to evaluate the effects of earnings momentum and earnings acceleration on the market value of equity for firms with differing operational efficiencies. In the first part, our empirical tests are based on sample data covering the period from 1999 to 2012. In the second part, our empirical tests are based upon sub-sample data covering the period from 2005 to 2012. Our expectation is that there will be differences in the parameters estimated over different time periods largely reflecting the changing environment in which Chinese capital markets have operated. Our results generally show that neither earnings momentum nor earnings acceleration exhibit a significant association with the market value of equity for firms listed on the SSE. Moreover, there are no significant differences in the empirical results we obtain based on the sample data covering the period from 1999 to 2012 and those based on sample data covering the period from 2005 to 2012. Section 4.4 looks at country characteristics and problems with the construction of the theoretical model itself for reasons that could explain our failure to find any kind of relationship between earnings momentum, earnings acceleration and the market value of equity for firms listed on the SSE. Section 4.4 also concludes this chapter.

4.2 Equity Valuation Model Incorporating Earnings Momentum and Acceleration

We begin our analysis by recalling from section 2.4 of Chapter 2 that it is conventional practice to state a firm's investment opportunity set in terms of the following first order system of stochastic differential equations:

$$\begin{pmatrix} \frac{da(t)}{dt} \\ \frac{dv(t)}{dt} \end{pmatrix} = \begin{pmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{pmatrix} \begin{pmatrix} a(t) \\ v(t) \end{pmatrix} + \begin{pmatrix} k_1 & 0 \\ 0 & k_2 \end{pmatrix} \begin{pmatrix} \frac{dz_1(t)}{dt} \\ \frac{dz_2(t)}{dt} \end{pmatrix}$$

or, in matrix notation:

$$\tilde{u}'(t) = Q\tilde{u}(t) + K\tilde{z}'(t)$$

Here:

$$\tilde{u}(t) = \begin{pmatrix} a(t) \\ v(t) \end{pmatrix}$$

is the vector whose elements are the instantaneous abnormal earnings, $a(t)$, attributable to equity at time t and the information variable, $v(t)$, that captures information relevant to the value of the firm's equity but which has not, as yet, been incorporated into the firm's accounting records. Moreover:

$$\tilde{u}'(t) = \begin{pmatrix} \frac{da(t)}{dt} \\ \frac{dv(t)}{dt} \end{pmatrix}$$

is the vector whose elements are the derivatives of the variables comprising the firm's investment opportunity set. Next, is the matrix:

$$Q = \begin{pmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{pmatrix}$$

whose elements, c_{11} , c_{12} , c_{21} and c_{22} , are the structural coefficients associated with the firm's investment opportunity set. The structural coefficients capture the sensitivity of increments in the variables comprising the firm's investment opportunity set to the existing levels of these variables. Moreover, K is a matrix whose diagonal elements are a set of "normalising" constants:

$$k_1 = \frac{(i - c_{11})(i - c_{22}) - c_{21}c_{12}}{(i - c_{22})} \text{ and } k_2 = \frac{(i - c_{11})(i - c_{22}) - c_{21}c_{12}}{c_{12}}$$

and where i is the cost of the firm's equity capital. The off diagonal elements of the matrix K are all zero. The final term in the system of stochastic differential equations is the vector:

$$z'(t) = \begin{pmatrix} \frac{dz_1(t)}{dt} \\ \frac{dz_2(t)}{dt} \end{pmatrix}$$

whose elements are the white noise terms associated with the variables comprising the firm's investment opportunity set. Thus, $\frac{dz_1(t)}{dt}$ and $\frac{dz_2(t)}{dt}$ are orthogonal white noise processes with variance parameters of σ_1^2 and σ_2^2 , respectively.

Now, if the firm is indefinitely constrained to operate within the investment opportunity set articulated above it then follows that the market value of its equity will turn out to be (Ohlson, 1995):

$$P(t) = b(t) + \frac{(i - c_{22})a(t)}{(i - c_{11})(i - c_{22}) - c_{12}c_{21}} + \frac{c_{12}v(t)}{(i - c_{11})(i - c_{22}) - c_{12}c_{21}}$$

where $b(t)$ is the book value of the firm's equity at time t . However, as noted in section 2.5 of Chapter 2 empirical studies show that equity values based on the above model generally underestimate actual equity values by at least 20 per cent. Here it is also important to note that recent developments in equity valuation theory (as discussed in section 3.5 of Chapter 3) show that the higher order derivatives of the determining variables, that is, the momentum and acceleration of the accounting information disclosed in a firm's financial statements, can have a significant impact on the market value of equity. Unfortunately, when (as with the above valuation model) an investment opportunity set is defined in terms of a first order system of stochastic differential equations it cannot take account of these momentum and acceleration phenomena. However, we have previously noted that it is possible to address this issue by stating the firm's investment opportunity set in terms of the following vector system of third order stochastic differential equations (Davidson & Tippett, 2012, pp. 295-97):

$$\begin{pmatrix} \frac{d^3 a(t)}{dt^3} \\ \frac{d^3 v(t)}{dt^3} \end{pmatrix} = \begin{pmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{pmatrix} \begin{pmatrix} a(t) \\ v(t) \end{pmatrix} + \sqrt{\eta(t)} \begin{pmatrix} k_1 & 0 \\ 0 & k_2 \end{pmatrix} \begin{pmatrix} \frac{dz_1(t)}{dt} \\ \frac{dz_2(t)}{dt} \end{pmatrix}$$

Here $\eta(t)$ is the expected present value of the firm's future cash flows under the assumption that it is constrained to operate within its existing investment opportunity set indefinitely into the future. Next, $\frac{d^3 a(t)}{dt^3}$ is the jerk (per unit time)

in the abnormal earnings and $\frac{d^3 v(t)}{dt^3}$ is the jerk (per unit time) in the information variable. The jerk of a firm's abnormal earnings and information variable captures the rate of change in the acceleration of these variables.

Moreover, $k_1 = \frac{(i^3 - c_{11})(i^3 - c_{22}) - c_{21}c_{12}}{(i^3 - c_{22})}$ and $k_2 = \frac{(i^3 - c_{11})(i^3 - c_{22}) - c_{21}c_{12}}{c_{12}}$ are

normalising constants. All other parameters are as previously defined. When a firm is indefinitely constrained to operate within the above investment opportunity set then Davidson and Tippett (2012 pp. 295-98) use procedures similar to those

employed with the Ohlson (1995) model to show that the market value of a firm's equity, $P(t)$, will turn out to be:

$$P(t) = b(t) + \frac{i^2(i^3 - c_{22})a(t) + i(i^3 - c_{22})a'(t) + (i^3 - c_{22})a''(t) + i^2c_{12}v(t) + ic_{12}v'(t) + c_{12}v''(t)}{(i^3 - c_{11})(i^3 - c_{22}) - c_{12}c_{21}}$$

where $a'(t) = \frac{da(t)}{dt}$ is the momentum in the firm's earnings and $v'(t) = \frac{dv(t)}{dt}$ is the

momentum in the other information variable; $a''(t) = \frac{d^2a(t)}{dt^2}$ is the acceleration in the

firm's earnings and $v''(t) = \frac{d^2v(t)}{dt^2}$ is the acceleration in the firm's other information

variable. Under this specification, note that $a'(t)$, $v'(t)$, $a''(t)$ and $v''(t)$ can have a significant impact on the market value of a firm's equity. Moreover, recall that the residual income variable can be re-stated as $a(t) = x(t) - ib(t)$, where $x(t)$ is the earnings figure reported on the firm's profit and loss account. Substituting this definition of the residual income variable into the above expression for the market value of the firm's equity shows:

$$P(t) = \beta_0 + \beta_1x(t) + \beta_2b(t) + \beta_3x'(t) + \beta_4x''(t) + e(t)$$

where $x'(t)$ is the momentum in the firm's earnings, $x''(t)$ is the acceleration in the firm's earnings, β_0 , β_1 , β_2 , β_3 and β_4 are valuation coefficients and $e(t)$ captures the error that arises from omitting all the terms associated with the information variable $v(t)$. Our subsequent empirical work will be based on a regression specification that is derived from this basic valuation model. Before this, however, we provide a detailed specification of the empirical data on which our regression procedures are based.

4.3 Sample Data, Descriptive Statistics and Empirical Results

4.3.1 Complete Data (from 1999 to 2012)

In recent years, there has been very strong growth in the Chinese economy with real GDP growth averaging 10.48% per annum for the period from 1992 until 2011. In 2010, China became the world's second largest economy. The Chinese stock exchanges have also experienced rapid growth and in the process, become increasingly more sophisticated. Indeed, they have been playing an important role in attracting funds for both domestic and foreign equity offerings and for the overall development of the Chinese economy. The SSE opened for trading on 19 December, 1990 and since this date has become a crucial component of the Chinese Government's agenda to move from a totally planned command economy towards a mixed economy. Since its inception the SSE has experienced rapid development in terms of the number of companies listed on its trading boards, trading volumes and overall market capitalisation. For example, whilst there were only seven listed companies on the first trading day of the SSE in 1990, by the end of December 2011 there were a total of 931 listed companies with a total market capitalisation of US\$2.3 trillion. The SSE now ranks as the fifth largest stock market in the world.

However, the interesting difference between the way other large stock markets function and the way the SSE operates is that stocks listed on the SSE are traded as either A-shares or B-shares. The original requirement was that A-shares were to be exclusively owned by Chinese citizens and were transacted exclusively in the Chinese Yuan. However, since China's admission to the World Trade Organisation (WTO) in 2001, Chinese capital markets are gradually being opened up to foreign capital investors. Since this date foreign financial institutions have started to invest in domestic brokerage and fund management companies. These joint venture companies now engage in a number of activities, including the underwriting of A-shares traded on the SSE (Seddighi & Nian, 2004). Moreover, in 2003 the Chinese government promulgated the Qualified Foreign Investment Institution (QFII) regulations. These regulations allow certain classes of foreign

institutional investors to directly purchase A-shares. Before 20 February, 2001, B shares could only be held by non-Chinese investors trading in foreign currencies. However, on 20 February, 2001, following approval by the State Council, the China Security Regulatory Commission (CSRC) allowed Chinese citizens to trade B-shares in foreign currencies. This means that since this date both foreigners and Chinese nationals have been allowed to purchase the B-shares of firms listed on the SSE (Fact Book, 2001). The developments and the distinct features of the SSE have attracted interest from more and more researchers, investors and policy makers. Given this, it is important to investigate the relationship between the market value of equity for firms listed on the SSE and the accounting information summarised in their published financial statements. In particular, assessing the impact of momentum and acceleration in accounting variables on equity values will assist in policy initiatives by government instrumentalities and capital market regulators and will also enable investors to improve the way in which they allocate resources across the various investment opportunities available to them. Our sample data is comprised entirely of A-shares given that by the end of 2011, the market capitalisation of B-shares is only 0.69% of the total capitalised value of the A-shares listed on the SSE.

Our sample data are comprised of N= 8,519 firm-years from the SSE and are drawn from the Datastream database. Our data includes all industrial groupings listed on the SSE and covers the period from 1999 until 2012. The starting point for our data is 1999 rather than 1990 when the SSE was founded. This is due to the fact that between 1993 and 1996 Chinese stock markets experienced an unprecedented bear period. This was partially due to the manipulation of stock prices in ways that were inconsistent with the listing requirements and trading rules of more developed capital markets. However, between early 1996 and 1999 individual investors joined with professionals and academics and launched a stream of initiatives that called for fair trading rules and a stringent enforcement of such rules in order to inhibit illegal trading activities. The public pressure generated by these initiatives goaded the CSRC into implementing a vigorous reform programme under which the security laws and regulations governing the operation of China's capital markets were brought more into line with those operating in western economies.

For example, the *Implementation Rules on Information Disclosures of Companies Issuing Public Shares* was implemented in 1993. Under these Rules minimum standards are set for the information which must be disclosed by companies listed on the SSE. Most importantly, the CSRC introduced China's first *Securities Law* in July 1999. The 1999 *Securities Law* when taken together with the 1994 *Company Law* has made it much more difficult for the kind of manipulation of stock prices that occurred in the early 1990's to occur again (Commission, 2008). It is for this and other reasons that we deliberately choose to base our empirical analysis on data after the promulgation of the 1999 *Securities Law*.

We begin the summary description of the data on which our empirical analysis is based by providing definitions of the dependent variable and each of the independent variables used in our empirical tests. For each firm-year, the market value of equity, $P(t)$, which is the dependent variable in our regression model, is defined as the stock price at the end of the fiscal year t .¹² All listed Chinese firms have the same fiscal year-end; namely, 31 December. Their annual reports have to be published by 30 April of the following year. To capture the relationship between the accounting variables used in our regression analysis and the market value of equity, we assume that the closing share price on 30 April each year fully reflects the market's reaction to the assimilated information contained in the financial reports covering the fiscal year ending up until 31 December of the

¹² Empirical analysis in this area is usually conducted by deflating all variables by the book value of equity, or the total assets of a firm in order to address problems of size and heteroskedasticity (Burgstaher & Dichev, 1997; Hayn, 1999; Morel, 2003; de Klerk & de Villiers, 2012). However, Davidson and Tippett (2012, pp. 245-249) show that when deflated variables are used in regression analysis it leads to a form of spurious correlation which results in biased and inconsistent parameter estimates as well as inflated t-statistics and R^2 statistics. Davidson and Tippett (2012, p. 247) also show that this problem can be addressed by choosing a deflating variable with a relatively small variance. Here, our empirical analysis shows that the firms from the Shanghai Stock Exchange comprising our sample issue new shares on average only once in every four years. This in turn will mean that the variance associated with changes in the number of shares on issue will be considerably lower than the variance associated with changes in either the book value of equity or the market value of equity. Hence, deflating all variables by the number of shares on issue will lead to relatively smaller biases in parameter estimates in comparison to deflating by either the book value of equity or the market value of equity. Our unreported empirical analysis of firms listed on the Shanghai Stock Exchange shows that using the book value of equity as a deflating variable leads to significant biases in parameter estimates as well as artificially raising the R^2 statistics to over 80% as a consequence of the spurious correlation effects identified in Davidson and Tippett (2012, pp. 245-249).

previous year. The market value of equity is adjusted for capital issues such as stock splits and dividend payments during the year (Datastream Datatype (P)).

In our price-level regression model, we have four explanatory (that is, independent) variables. First, $b(t)$ represents the book value of equity per share at the beginning of year t . It represents the book value (proportioned common equity divided by outstanding shares) at the company's fiscal year end, $(t - 1)$ (Datastream mnemonic WC05476). The reason that we use the book value disclosed at the end of year $(t - 1)$ rather than book value disclosed at the end of year t is that the latter includes earnings for year t as a component (Burgstahler & Dichev, 1997, p. 195). In other words, using book value at year $(t - 1)$ is a more appropriate explanatory variable for the market value of equity on 30 April in year $(t + 1)$, since it does not include the earnings figure for the current year, t . As such, it allows our regression model to distinguish clearly between the impact that earnings and the impact that book value will have on the market value of equity. Second, $x(t)$ is earnings per share disclosed for year t . It represents the earnings for the 12 months ended the fiscal year t . Earnings per share is profit after tax, minority interest and preferred dividends but before extraordinary items (Datastream mnemonic WC05201). Third, $x'(t)$ is defined as earnings momentum. It measures the change in earnings from year $(t - 1)$ to year t and is calculated as:¹³

$$x'(t) \approx x(t) - x(t - 1)$$

¹³ Momentum is normally expressed in terms of the first derivative. However, the first derivative can be approximated by taking the first difference in the earnings variable and then dividing it by the length of the period over which the first difference is taken:

$$x'(t) = \frac{\Delta x(t)}{\Delta t} + O[(\Delta t)^2] = \frac{x(t) - x(t - \Delta t)}{\Delta t} + O[(\Delta t)^2]$$

Since $\Delta t = 1$ year in our empirical analysis this explains the definition of momentum given here.

Finally, $x''(t)$ denotes earnings acceleration. It measures the rate of change in earnings momentum and is calculated as:¹⁴

$$x''(t) \approx [x(t) - x(t - 1)] - [x(t - 1) - x(t - 2)] = [x(t) - 2x(t - 1) + x(t - 2)]$$

The data for the book value of equity are collected as far back as the year 1999; the data for earnings are collected from the year 2000 onwards, whilst the data for the market value of equity are collected from the year 2002 onwards. Several observations were lost due to system missing values. We eliminate firm-year data where either the market value of equity or any one or more of the four independent variables required for the regression analysis are missing or not available. We also eliminate firm-year data with a zero book value, as we assess firm efficiency in terms of the ratio of the firm's earnings to the book value of its equity.

4.3.1.2 Descriptive Statistics and Empirical Results on Pooled Data from 1999 to 2012

After eliminating 723 firm-years of missing data and/or firm-year data with a zero book value our regression procedures are based on a total of $N = 8,519$ firm-years of data. Finally, it has been widely accepted that regression models using standardised or centred variables are very important for dealing with potential problems of multi-collinearity as well as in interpreting the interactions between the independent variables. In particular, centring the independent variables in a regression model completely addresses issues of non-essential multi-collinearity (Afshartous and Preston, 2011, p. 8; Cohen et al., 2003, p. 264). As a consequence of this all our estimation procedures are based on centred data.

¹⁴ Acceleration is normally expressed in terms of the second derivative. However, the second derivative can be approximated by taking the second difference in the earnings variable and then dividing it by the square of the length of the period over which the first difference is taken:

$$x''(t) = \frac{\Delta x^2(t)}{(\Delta t)^2} + O[(\Delta t)^2] = \frac{x(t) - 2x(t - \Delta t) + x(t - 2\Delta t)}{(\Delta t)^2} + O[(\Delta t)^2]$$

Since $\Delta t = 1$ year in our empirical analysis this explains the definition of momentum given here.

Table 4.1 provides summary statistical information relating to the data on which our regression procedures are based. This table shows that the mean and median of the centred book value of equity across the $N = 8,519$ firm-years comprising our sample are zero and -0.23, respectively. Likewise, the standard deviation of the centred book values across our sample data is 1.81. Finally, the minimum centred book value in our sample is -26.23 whilst the maximum centred book value is 42.12. The descriptive statistics associated with the other variables summarised in Table 4.1 are to be similarly interpreted. The difference between the median value of earnings (book value) and the mean value of earnings (book value) is very small which indicates that the data do not suffer from serious skewness.

Table 4.1
Distributional Properties
of Full-sample Data
1999-2012
Firm-Year N = 8,519

	x(t)	b(t)	x'(t)	x''(t)
Mean	0.00	0.00	0.00	0.00
Median	-0.03	-0.23	0.00	0.00
Std. Deviation	0.59	1.81	0.65	1.05
Minimum	-28.24	-26.23	-20.64	-18.63
Maximum	8.30	42.12	22.46	43.10

Variable Definitions: $b(t)$ = Book value of equity per share at the beginning of year t . It represents the book value (proportioned common equity divided by outstanding shares) at the company's fiscal year end, $(t - 1)$ (Datastream mnemonic WC05476). $x(t)$ = Earnings per share for year t . It represents the earnings for the 12 months ended the fiscal year t . Earnings per share is profit after tax, minority interest and preferred dividends but before extraordinary items (Datastream mnemonic WC05201). $x'(t) \approx x(t) - x(t - 1)$ = Earnings momentum. It measures the change in earnings from year $(t - 1)$ to year t . $x''(t) \approx [x(t) - 2x(t - 1) + x(t - 2)]$ = Earnings acceleration. It measures the rate of change in earnings momentum. All descriptive statistics variables are based on centred data.

Table 4.2 contains the estimates of the coefficients and the associated t-scores generated by the three price-level regression models. We use White's (1980) heteroskedastic-consistent covariance matrix estimation procedure in all regressions to correct the estimates for any unknown forms of heteroskedasticity. The first price-level regression (M1) is a simple linear equity valuation model with only the earnings and book value of equity as independent variables. The second price-level regression (M2) includes earnings, the book value of equity and earnings momentum as explanatory variables. The third price-level regression (M3) incorporates earnings, the book value of equity, earnings momentum and earnings acceleration as explanatory variables. All regressions are based on the $N = 8,519$ firm-year observations comprising our sample. Student t-scores are listed below all estimates of the regression coefficients.

The empirical results show that for the M1 regression specification the coefficients associated with the book value variable and the earnings variable are both positive and highly significant. The adjusted R^2 value is 23.50%. When the regression model is augmented to include the earnings momentum variable as in the M2 regression specification, the coefficients associated with the book value and earnings variables are essentially unchanged. Similarly, the t-statistics associated with these parameter estimates are also unchanged and thus, remain positive and highly significant. In contrast, the coefficient associated with earnings momentum is small and negative with an insignificant t-statistic. Finally the R^2 value for the M2 regression is 23.51% which is barely changed in comparison to the R^2 value of 23.50% for the M1 regression. Matters do not improve much with the M3 regression model which augments the M2 model with the earnings acceleration variable. Again the coefficients associated with the book value and earnings variables are essentially unchanged. Likewise, the t-statistics associated with these parameter estimates are also unchanged and thus, remain positive and highly significant. In contrast, the coefficients associated with the earnings momentum and the earnings acceleration variables are small and statistically insignificant. Finally the R^2 value for the M3 regression is 23.56% which is barely changed in comparison to the R^2 value of 23.50% for the M1 regression. Hence, the overall

conclusion that one obtains from these three regression models is that earnings momentum and earnings acceleration do not have much of an impact on the market value of equity for stocks listed on the SSE. It can also be observed from the empirical results that the coefficients associated with the earnings variable are more than three times those associated with the book value variable. This means that the market value of equity is more sensitive to the change in earnings than it is to changes in book value. Finally, Table 4.2 summarises the F-statistics for M1, M2 and M3 regression models based on the hypothesis that the R^2 value is insignificantly different from zero as well as the Durbin-Watson first order autocorrelation statistics for serial correlation in the residuals. Note that all F-statistics are statistically significant at any reasonable level thereby confirming that one can reject the maintained hypothesis that $R^2 = 0$ for all three regression models. For the Durbin-Watson statistics our sample of $N = 8,519$ firm-year observations are ordered from lowest to highest in terms of the profitability ratio, $q(t)$. The residuals from the ordered sequence based on the $q(t)$ ratios are then calculated for all three regression models and the Durbin-Watson statistics are computed for each model separately. The Durbin-Watson statistics are all slightly below their expected value of two, thereby indicating that the residuals in the regression models vary systematically according to the level of firm profitability. Fortunately, this is an issue that can be addressed by dividing firms into one of three levels of operational efficiency. Before doing so, however, we test the M1, M2 and M3 regression models for the presence of multi-collinearity in the independent variables.

Table 4.2
Coefficient Estimates for First Order Model (M1), Second Order Model (M2) and Third Order Model (M3)
for the Full-sample Data
1999-2012

N= 8,519 Firm-Years

$$\mathbf{M1:} P(t) = \beta_0 + \beta_1 x(t) + \beta_2 b(t) + e(t)$$

$$\mathbf{M2:} P(t) = \beta_0 + \beta_1 x(t) + \beta_2 b(t) + \beta_3 x'(t) + e(t)$$

$$\mathbf{M3:} P(t) = \beta_0 + \beta_1 x(t) + \beta_2 b(t) + \beta_3 x'(t) + \beta_4 x''(t) + e(t)$$

Valuation Model	Model Coefficients t-statistics Listed Below Coefficients					Model Adjusted R ²	Model F-Statistic & D-W Value
	β_0	β_1	β_2	β_3	β_4		
First Order Model (M1)	8.20 121.00	4.13 3.82	1.29 6.66			23.50%	F=1309.15 D-W=1.79
Second Order Model (M2)	8.20 121.00	4.25 3.88	1.27 6.31	-0.20 -0.31		23.51%	F=873.55 D-W=1.79
Third Order Model (M3)	8.2 121.10	4.5 3.97	1.24 6.17	-0.80 -0.79	0.34 0.76	23.56%	F=657.21 D-W=1.79

White (1980) adjusted t-statistics are listed below the regression coefficients.

Variable Definitions: $b(t)$ = Book value of equity per share at the beginning of year t . It represents the book value (proportioned common equity divided by outstanding shares) at the company's fiscal year end, $(t - 1)$ (Datastream mnemonic WC05476). $x(t)$ = Earnings per share for year t . It represents the earnings for the 12 months ended the fiscal year t . Earnings per share are profit after tax, minority interest and preferred dividends but before extraordinary items (Datastream mnemonic WC05201). $x'(t) \approx x(t) - x(t - 1)$ = earnings momentum. It measures the change in earnings from year $(t - 1)$ to year t . $x''(t) \approx [x(t) - 2x(t - 1) + x(t - 2)]$ = earnings accelerations. It measures the rate of change in earnings momentum.

It is well known that multi-collinearity can lead to inefficient estimates of the regression coefficients. Many methods have been implemented for identifying the existence of multi-collinearity in the independent variables such as the variance inflation factor (VIF) test, Farrar-Glauber test, the auxiliary regression procedure, etc. In our empirical study, we implemented the condition number test in order to detect potential problems of multi-collinearity. If the condition number is above 15, it can raise concerns about the existence of co-linear independent variables (Belsley et al., 2005). However, the results of the condition number test, as reported in Table 4.3 indicate that there is no reason to believe that multi-collinearity is an issue with our regression procedures. Note in particular how Table 4.3 returns a condition index of 5.024 which is well within the generally accepted value of 15 at which multi-collinearity in the independent variables may become an issue.

Table 4.3 Multi-collinearity Diagnostics (Full-sample)

Model Dimension	Eigenvalue	Condition Index	Variance Proportions				
			(Constant)	Earnings	Book Value	Earnings Momentum	Earnings Acceleration
1	2.158	1	0	0.04	0.01	0.03	0.04
2	1.039	1.441	0	0.09	0.6	0	0
3	1	1.469	1	0	0	0	0
4	0.717	1.735	0	0.28	0.2	0	0.12
5	0.086	5.024	0	0.59	0.19	0.97	0.84

4.3.1.3 Descriptive Statistics and Empirical Results on Efficiency Groups from 1999 to 2012

We have previously noted (as in section 2.6 in Chapter 2 and section 3.4 in Chapter 3) that the valuation coefficients associated with a firm's earnings and the book value of its equity will change in response to changes in its operational efficiency. In other words, market participants will change their focus from certain explanatory variables in the equity valuation process to others as the firm's profitability level changes. Given this, we also conduct price-level regressions based on firms with different levels of operational efficiency. We rank equity

securities on the basis of their most recent profitability, $q(t)$, which we have previously defined as the ratio of earnings to the book value of equity, or:

$$q(t) = \frac{x(t)}{b(t-1)}$$

where $x(t)$ is earnings per share for year t , $b(t-1)$ is the book value of equity per share at the end of year $(t-1)$ and $q(t)$ measures the firm's ability to generate profits from assets, thereby measuring its operational efficiency (Chen & Zhang, 2002, p. 7). All firm-year data with a negative book value are included in the low-efficiency group, since otherwise firm-years with a negative book value and negative earnings will return a positive $q(t)$ ratio and would therefore be included in either the steady-state or high-efficiency groups.

In our efficiency sub-sample empirical tests, all firm-year data are assigned to three equally numerous groups. The bottom tertile is thus comprised of the $N_1 = 2,840$ firm-years with the lowest operational efficiency; the middle tertile is comprised of the $N_2 = 2,840$ firm-years with steady-state or moderate operational efficiency; while the top tertile is comprised of the $N_3 = 2,839$ firm-years with the highest level of operating efficiency.

A summary of the distributional properties of the earnings, book value of equity, earnings momentum and earnings acceleration variables across the three levels of operational efficiency is contained in Table 4.4. This table shows that the mean and median of the centred book value of equity across the $N_1 = 2,840$ firm-years comprising our sample of low-efficiency observations are zero and -0.16, respectively. Likewise, the standard deviation of the centred book values across our sample of low-efficiency observations is 2.40. Finally, the minimum centred book value in our sample is -26.07 whilst the maximum centred book value is 42.29. The remaining statistics summarised in Table 4.4 are to be similarly interpreted.

Table 4.4
Distributional Properties of Low-efficiency, Steady-state and High-efficiency Sub-samples
1999-2012

	x(t)	b(t)	x'(t)	x''(t)
Low-efficiency (Firm-Year $N_1 = 2,840$)				
Mean	0.00	0.00	0.00	0.00
Median	0.16	-0.16	0.05	0.03
Std. Deviation	0.85	2.40	1.04	1.65
Minimum	-27.95	-26.07	-20.54	-18.58
Maximum	5.39	42.29	22.56	43.15
Steady-state (Firm-Year $N_2 = 2,840$)				
Mean	0.00	0.00	0.00	0.00
Median	-0.02	-0.23	0.00	0.00
Std. Deviation	0.10	1.27	0.19	0.37
Minimum	-0.15	-2.11	-4.01	-7.17
Maximum	0.81	10.11	2.49	5.06
High-efficiency (Firm-Year $N_3 = 2,839$)				
Mean	0.00	0.00	0.00	0.00
Median	-0.11	-0.35	-0.06	-0.03
Std. Deviation	0.41	1.57	0.33	0.65
Minimum	-0.41	-2.08	-4.89	-16.73
Maximum	8.02	15.64	5.67	11.15

Variable Definitions: $b(t)$ = Book value of equity per share at the beginning of year t . It represents the book value (proportioned common equity divided by outstanding shares) at the company's fiscal year end, $(t - 1)$ (Datastream mnemonic WC05476). $x(t)$ = Earnings per share for year t . It represents the earnings for the 12 months ended the fiscal year t . Earnings per share is profit after tax, minority interest and preferred dividends but before extraordinary items (Datastream mnemonic WC05201). $x'(t) \approx x(t) - x(t - 1)$ = Earnings momentum. It measures the change in earnings from year $(t - 1)$ to year t . $x''(t) \approx [x(t) - 2x(t - 1) + x(t - 2)]$ = Earnings acceleration. It measures the rate of change in earnings momentum. All descriptive statistics variables are based on centred data.

Table 4.5 provides a summary of the regression results for the three efficiency sub-samples; t-scores are listed below the estimated regression coefficients. Our empirical results show that the coefficients associated with the book value and earnings variables as generated by the regression model M1 based upon sample data consisting of low efficient firms are significant and positive. However, the adjusted R^2 value is only 2.41%. We thus augment our regression model (M1) by including earnings momentum (as in M2) or earnings momentum and acceleration together (as in M3) along with the earnings and book value of equity as component(s) of the price-level regression. However, the t-scores associated with the coefficients on earnings momentum and earnings acceleration show that for low-efficiency firms, neither earnings momentum nor earnings acceleration exhibits any value relevance to the stock prices of firms listed on the SSE. Moreover, including earnings momentum and earnings acceleration in the regression model does not lead to any improvement in explanatory power with the R^2 value hovering around 2.40% for all three regression models. It can also be noted that in the M3 regression model where earnings momentum and earnings acceleration are incorporated as explanatory variables, the coefficient associated with book value is highly significant whilst the coefficient associated with earnings has declined in comparison to its value in the M1 and M2 regression models to the point where it is at best, marginally significant. This result seems consistent with the prior literature which shows that for low-efficiency firms, book value has a more compelling role to play than earnings in the determination of equity value. However, the slight decline in the R^2 value for the M3 regression model suggests that with the incorporation of earnings momentum and earnings acceleration, the M3 model has no particular advantage over the more parsimonious M1 regression model. Given this, we cannot conclude for low-efficiency firms listed on the SSE between 1999 and 2012, that book value plays a more predominant role than earnings in the determination of market value of equity.

The empirical results for the steady-state sub-sample of firms are summarised in the second panel of Table 4.5. Note how Table 4.5 shows that the coefficients associated with the book value and earnings variables are positive and highly

significant across each of the M1, M2 and M3 regression models. When earnings momentum is taken into the valuation process, as in the M2 regression model, it turns out to have a positive and highly significant impact on the market value of equity with an estimated regression (that is, valuation) coefficient of 2.90 and corresponding t-score of 3.55. We then augment the M2 regression model by incorporating earnings acceleration. This leads to the M3 regression model. Under M3, earnings momentum still exhibits a positive and highly significant association with the market value of equity with an estimated valuation coefficient of 3.60 and a corresponding t-score amounting to 3.18. However, the coefficient associated with earnings acceleration, -0.43, is small and insignificant with a t-score amounting to -0.82. Here it needs to be emphasised, however, that whilst the M2 and M3 regression models suggests that earnings momentum has a significant impact on the market value of equity for the steady-state firm-years comprising our sample, it is nonetheless the case that there is only a trivial increase in the R^2 statistic as we move from the M1 regression model (where $R^2 = 24.57\%$) to the M2 regression model (where $R^2 = 24.85\%$) to the M3 regression model (where $R^2 = 25.86\%$). Thus, the inclusion of earnings momentum as a component of the equity valuation model does not appear to bring any particular advantage over the more parsimonious M1 model based on earnings and the book value of equity alone. It can also be observed from the results summarised in Table 4.5 that for steady-state firms the coefficients associated with the earnings variable are between 9.20 and 9.53, in comparison with the earnings coefficients generated by the low-efficiency firms which are between 0.36 and 0.46. The considerable increase in the coefficients associated with the earnings variable as one moves from the low-efficiency group to the steady-state efficiency group indicates that the importance of earnings information in the investment decision making process changes substantially when a firm's profitability level changes. Moreover, the coefficients associated with the earnings variable for steady-state efficiency firms are roughly nine times those associated with the book value variable. This suggests that for firms in steady-state efficiency market participants view earnings as containing more information about a firm's operational efficiency than the book value of equity, and thus, the market value of equity for firms falling in the steady-

state efficiency group are more sensitive to changes in earnings than to changes in book value.

We now turn the focus of our attention to the high-efficiency sub-sample of firms. The results summarised in the third panel of Table 4.5 show that neither earnings momentum nor earnings acceleration contributes significantly to the equity values of firms comprising the high efficiency classification. In particular, the coefficient on the earnings momentum variable in M3 is -0.76 with a t-score of -0.92. Similarly, the coefficient on the earnings acceleration variable in M3 is 0.27 with the corresponding t-score of 0.88. Moreover, the adjusted R^2 values associated with the three regression models in the high-efficiency classification show that neither earnings momentum nor earnings acceleration adds any explanatory power to the parsimonious equity valuation model, M1, based on earnings and book value alone. Here there is only a trivial increase in the value of the R^2 statistic as we move from the M1 regression model (where $R^2 = 51.50\%$) to the M2 regression model (where $R^2 = 51.50\%$) and finally to the M3 regression model (where $R^2 = 51.51\%$). Of more significance, however, is that our empirical results show that earnings has a more compelling role to play than book value in the determination of the equity values of the high efficiency sub-sample of firms. Specifically, the coefficients associated with the book value variable are small and insignificantly different from zero in all three regression models. Moreover, the corresponding t-score values indicate that the book value variable has an inconsequential impact on the market value of equity for the high-efficiency classification of firms. This is consistent with prior empirical work which finds for high-efficiency firms that earnings is the predominant determining variable of equity values (Burgstahler & Dichev, 1997; Collins et al., 1999; etc.). It will also be noted from the results summarised in Table 4.5 that the coefficients associated with the earnings variable increase from about 9 for steady-state efficiency firms to 16 for high-efficiency firms. Again this means that for firms with high efficiency, market participants view earnings as containing more information about a firm's operational efficiency than the book value of equity and thus, the market value of equity for firms falling in this group are more sensitive to the changes in earnings

than to changes in book value. Table 4.5 also summarises the Durbin-Watson statistics associated with each of our regression models. The calculation of the Durbin-Watson statistics follows our previous procedure of ranking firm-years within each efficiency classification in terms of the profitability ratio, $q(t)$. The residuals from the ordered sequence based on the $q(t)$ ratios are then calculated for all three regression models and the Durbin-Watson statistics are computed for each model separately. For all three regression models and all three efficiency classifications the Durbin-Watson statistics cluster around their expected value of two thereby confirming that there does not appear to be any significant problems with autocorrelated residuals. Thus, classifying firms into one of three groups based on their operational efficiency addresses the issue of serial correlation that emerged with our regression procedures based on the pooled data. Moreover, all F-statistics are statistically significant at any reasonable level thereby confirming that one can reject the maintained hypothesis that $R^2 = 0$ for all three regression models.

Table 4.5

Coefficients Estimates for First Order Model (M1), Second Order Model (M2) and Third Order Model (M3) for Low-efficiency,

Steady-state and High-efficiency Sub-samples

1999-2012

$$\mathbf{M1:} P(t) = \beta_0 + \beta_1 x(t) + \beta_2 b(t) + e(t)$$

$$\mathbf{M2:} P(t) = \beta_0 + \beta_1 x(t) + \beta_2 b(t) + \beta_3 x'(t) + e(t)$$

$$\mathbf{M3:} P(t) = \beta_0 + \beta_1 x(t) + \beta_2 b(t) + \beta_3 x'(t) + \beta_4 x''(t) + e(t)$$

Valuation Model	Model Coefficients t-statistics Listed Below Coefficients					Model Adjusted R ²	Model F-statistic & D-W Value
	β_0	β_1	β_2	β_3	β_4		
Low-efficiency (Firm-Year N ₁ = 2,840) First Order Model (M1)	6.54	0.46	0.28			2.41%	F=36.06 D-W=1.97
	81.05	3.92	3.68				
Second Order Model (M2)	6.54	0.37	0.29	0.13		2.43%	F=24.58 D-W=1.97
	81.07	2.88	3.68	1.27			
Third Order Model (M3)	6.54	0.36	0.29	0.16	-0.02	2.40%	F=18.43 D-W=1.97
	81.07	1.81	3.38	0.52	-0.08		

Steady-state (Firm-Year $N_2 = 2,840$) First Order Model (M1)	7.35	9.53	1.11			24.57%	F=463.26
	96.37	4.31	5.65				D-W=1.97
Second Order Model (M2)	7.35	9.48	1.17	2.9		25.85%	F=330.95
	97.22	4.36	6.09	3.55			D-W=1.97
Third Order Model (M3)	7.35	9.2	1.19	3.6	-0.43	25.86%	F=248.55
	97.24	4.29	6.25	3.18	-0.82		D-W=1.97
High-efficiency (Firm-Year $N_3 = 2,839$) First Order Model (M1)	10.72	16.53	0.42			51.50%	F=1507.90
	80.87	7.09	1.48				D-W=1.94
Second Order Model (M2)	10.72	16.85	0.37	-0.48		51.50%	F=1005.6
	80.88	6.85	1.25	-0.74			D-W=1.94
Third Order Model (M3)	10.72	16.91	0.36	-0.76	0.27	51.51%	F=754.64
	80.9	6.82	1.22	-0.92	0.88		D-W=1.94

White (1980) adjusted t-statistics are listed below the regression coefficients.

Variable Definitions: $b(t)$ = Book value of equity per share at the beginning of year t . It represents the book value (proportioned common equity divided by outstanding shares) at the company's fiscal year end, $(t - 1)$ (Datastream mnemonic WC05476). $x(t)$ = Earnings per share for year t . It represents the earnings for the 12 months ended the fiscal year t . Earnings per share are profit after tax, minority interest and preferred dividends but before extraordinary items (Datastream mnemonic WC05201). $x'(t) \approx x(t) - x(t - 1)$ = earnings momentum. It measures the change in earnings from year $(t - 1)$ to year t . $x''(t) \approx [x(t) - 2x(t - 1) + x(t - 2)]$ = earnings acceleration. It measures the rate of change in earnings momentum.

Finally, we also ran the condition number test in order to assess whether our regression procedures might be afflicted by problems of multi-collinearity. Here it will be recalled that a condition number above 15 signals potential problems with co-linear variables. However, the results of the condition number tests, as reported in Tables 4.6 through Table 4.8, show that there is no reason to believe multi-collinearity is an issue with any of our regression models. Note in particular how the largest condition index across the three regression models amounts to 7.214 which is well within the generally accepted value of 15 at which multi-collinearity in the independent variables may become an issue.

The overall conclusion that one can draw from our regression analysis is that earnings momentum and earnings acceleration are not determining factors of the market value of equity for firms listed on the SSE. Although earnings momentum occasionally exhibits a significant correlation with the market value of equity - particularly for firms in the moderate efficiency classification¹⁵ - the models which add earnings momentum as an explanatory variable only lead to minor increases in explanatory power in comparison to the more parsimonious models based on earnings and the book value of equity alone. Our empirical results thus lead to the conclusion that the models which add earnings momentum as an explanatory variable do not provide a better description of the way equity prices evolve than the more parsimonious model based on earnings and book value alone.

¹⁵ Here it will be recalled (as in section 1.4 on p. 8) that I use the terms “moderate efficiency” and “steady-state efficiency” interchangeably.

Table 4.6 Multi-collinearity Diagnostics (Low-efficiency Sub-sample)

Model Dimension	Eigenvalue	Condition Index	Variance Proportions				
			(Constant)	Earnings	Book Value	Earnings Momentum	Earnings Acceleration
1	2.354	1	0	0.03	0.03	0.01	0.02
2	1	1.534	1	0	0	0	0
3	0.894	1.622	0	0.01	0.63	0	0.03
4	0.707	1.825	0	0.3	0.16	0	0.03
5	0.045	7.214	0	0.66	0.18	0.98	0.92

Table 4.7 Multi-collinearity Diagnostics (Steady-state Sub-sample)

Model Dimension	Eigenvalue	Condition Index	Variance Proportions				
			(Constant)	Earnings	Book Value	Earnings Momentum	Earnings Acceleration
1	2.109	1	0	0.03	0.03	0.03	0.03
2	1.606	1.146	0	0.03	0.03	0.05	0.05
3	1	1.452	1	0	0	0	0
4	0.175	3.474	0	0.11	0.1	0.7	0.7
5	0.11	4.377	0	0.83	0.84	0.22	0.22

Table 4.8 Multi-collinearity Diagnostics (High-efficiency Sub-sample)

Model Dimension	Eigenvalue	Condition Index	Variance Proportions				
			(Constant)	Earnings	Book Value	Earnings Momentum	Earnings Acceleration
1	1.912	1	0	0.07	0.06	0.06	0.03
2	1.3	1.213	0	0.01	0.07	0.13	0.28
3	1	1.383	1	0	0	0	0
4	0.613	1.766	0	0.01	0.06	0.39	0.67
5	0.174	3.311	0	0.91	0.81	0.43	0.02

4.3.2 Complete Data (from 2005 to 2012)

Here we would note that the prior literature suggests that the information dissemination mechanism within a country may help to explain the way market prices react to accounting information. In other words, the degree of protection provided to outside shareholders (in contrast to “insider” shareholders) within a country’s legal and regulatory system will hinder or enhance the market’s sensitivity to the firm specific information disclosed by a firm. In markets with high levels of corruption or low levels of investor protection it is highly likely that market prices will be manipulated by insiders (Bhattacharya et al., 2000). In situations like this, stock prices will quickly reflect the information held by insiders before the financial reports or announcements that contain such information are publicly disclosed. When the financial information eventually does become public, it will have no further impact on stock prices. This in turn creates the appearance of investor under-reaction to the public disclosure of firm-specific news. This also means that in such markets stock prices are unlikely to reflect any earnings momentum effects (Hong et al., 2003). The empirical evidence suggests that insider trading causes stock prices in developing countries such as, for example, Mexico to fully incorporate firm-specific information before its public release. Therefore in Mexico, corporate news announcements are not accompanied by any abnormal returns, return volatility, trading volume or bid-ask spread movements (Bhattacharya et al., 2000). Other empirical studies also suggest that the degree of protection rendered to outside shareholders is positively associated with the efficiency levels of its capital markets (Porta et al., 1997). While similar studies have not been conducted in China, it is not surprising that earnings momentum appears to have had such little impact on Chinese stock prices given the empirical results summarised on this issue for other developing countries such as Mexico.

In the past 20 years, the pace of development of the SSE has been extraordinary. Nonetheless, serious obstacles will need to be overcome if further development of the SSE and Chinese capital markets in general, is to occur. A significant issue here stems from the relative immaturity of the legal and regulatory systems that underscore the operation of Chinese capital markets. We have previously noted

how there were important developments in Chinese securities law in the early part of our sample period and how the gradual imposition of new investor protection laws in the period leading up to 2006 could have suppressed any earnings momentum effects on stock prices. Since the first *Securities Law* was promulgated in 1999, the Chinese government has introduced further market-oriented laws, policies and measures in order to improve the fairness and efficiency of Chinese financial markets. In particular, since China's admission to the World Trade Organisation (WTO) in 2001, Chinese capital markets have been opened up to foreign capital investment and there has been an acceleration in the legal and administrative reform process. For example, in 2001 the CSRC stipulated that all listed companies should disclose quarterly financial and other relevant information. In 2002, the *Notice on the Transfer of State-Owned Shares and Corporate Shares of Listed Companies to Foreign Investors Law* permitted foreign companies to purchase the stock of state-owned enterprises (Geretto & Pauluzzo, 2012). Since 2003, the National People's Congress has implemented a continuing programme to amend the Chinese *Securities Law* and the *Company Law*. In particular, major revisions were announced to these laws in 2005 and subsequently enacted in 2006. Moreover, in order to strengthen the law enforcement and supervision of Chinese capital markets, in 2002 the Securities Crime Investigation Bureau of the Ministry of Public Security was set up to investigate illegal activities in the securities and futures markets in conjunction with the CRSC. In 2007, a centralised enforcement system was developed when the CSRC set up the Sanction Committee, Chief Enforcement Office and the Law Enforcement Task Force and reinforced its enforcement offices which were set up in the local supervisory bureaus with a large workforce at local supervisory offices. Since the issue of the *Opinions of the State Council on Promoting the Reform, Opening and Steady Growth of Capital Market* in 2004, the State Council has commenced another round of reforms. These reforms include the implementation of non-tradable share reforms, improvements in the quality of financial reporting by listed firms, the restructuring of securities firms, greater access for foreign institutional investors and reforms to the IPO process (Commission, 2008). Considerations of space mean that we can only summarise the more salient features of the reforms and developments that have

occurred in Chinese capital markets in the period leading up to 2006. But we would emphasise that the reform agenda implemented over this period has had a profound impact on the overall development of the legal and regulatory system on which the operation of the Chinese capital markets is based. The SSE in particular has experienced substantial changes in terms of market expansion, infrastructure, market regulation and security products offered because of the changes made to the legal and regulatory framework during this period. Given the significance of these reforms we now determine the impact that earnings momentum and earnings acceleration might have had on the market value of equity for firms listed on the SSE over the period from 2005 until 2012.

4.3.2.1 Descriptive Statistics and Empirical Results on Pooled Data from 2005 to 2012

Table 4.9 provides summary statistical information relating to the composition of the sub-sample data covering the period from 2005 until 2012 on which our regression analysis is based. Table 4.9 shows that the mean and median of the centred book value of equity across the $N = 4,227$ firm-years comprising our sample are zero and -0.22, respectively. Likewise, the standard deviation of the centred book values across our sample data is 1.84. Finally, the minimum centred book value in our sample is -26.56 whilst the maximum centred book value is 15.58. The descriptive statistics of other variables summarised in Table 4.9 are to be similarly interpreted. The difference between the median value of earnings (book value) and the mean value of earnings (book value) is very small and means that there is little evidence of skewness in our data. Here we would also note that book value data are collected from 2006 onwards; earnings data are collected from 2005 onwards and data relating to the market value of equity are collected from 2008 onwards. The market value of equity, the book value of equity, the earnings, earnings momentum and earnings acceleration variables are all defined as previously. We would also note that several observations were lost due to system missing values. To facilitate our price-level regressions, we eliminate firm-year data where the market value of equity is missing or where one or more of the four independent variables is missing. We also eliminate firm-year data with zero book

values, as we again divide the data into three sub-groups based upon firms' operational efficiency as measured by the earnings to book value ratio, $q(t)$. We also seek to minimise any issues that may arise from co-linear independent variables by basing all our regression models on centred data.

As previously, we rank equity securities on the basis of the profitability measure:

$$q(t) = \frac{x(t)}{b(t - 1)}$$

where $x(t)$ is earnings per share for year t and $b(t - 1)$ is book value of equity per share at the end of year $(t - 1)$. Here it will be recalled that $q(t)$ measures the firm's ability to generate profits from its assets, thereby providing a measure of its operational efficiency.

Table 4.9
Distributional Properties
of Full-sample Data
2005-2012
Firm-Year N = 4,227

	x(t)	b(t)	x'(t)	x''(t)
Mean	0.00	0.00	0.00	0.00
Median	-0.05	-0.22	-0.02	0.01
Std. Deviation	0.60	1.84	0.65	1.12
Minimum	-22.08	-26.56	-20.53	-18.62
Maximum	8.21	15.58	18.81	39.34

Variable Definitions: $b(t)$ = Book value of equity per share at the beginning of year t . It represents the book value (proportioned common equity divided by outstanding shares) at the company's fiscal year end, $(t - 1)$ (Datastream mnemonic WC05476). $x(t)$ = Earnings per share for year t . It represents the earnings for the 12 months ended the fiscal year t . Earnings per share is profit after tax, minority interest and preferred dividends but before extraordinary items (Datastream mnemonic WC05201). $x'(t) \approx x(t) - x(t - 1)$ = Earnings momentum. It measures the change in earnings from year $(t - 1)$ to year t . $x''(t) \approx [x(t) - 2x(t - 1) + x(t - 2)]$ = Earnings acceleration. It measures the rate of change in earnings momentum. All descriptive statistics variables are based on centred data.

Table 4.10 summarises the estimated coefficients and their associated t-scores for the independent variables on which our three regression models are based. The first regression model, M1, is a simple linear equity valuation model with only earnings and book value as independent variables. The second regression model, M2, is an equity valuation model with earnings, book value and earnings momentum as explanatory variables. The third regression model, M3, is an equity valuation model that incorporates earnings, book value, earnings momentum and earnings acceleration as explanatory variables. All regressions are based on the $N = 4,227$ firm-year observations comprising our sub-sample data. All t-scores are listed below the estimated regression coefficients.

The empirical results for the parsimonious M1 model show that the coefficients associated with both book value and earnings are positive and highly significant with an adjusted R^2 value of 27.24%. We then augment the M1 regression model by including earnings momentum as an additional variable in the M2 regression model. Moreover the M3 regression model incorporates earnings acceleration as a fourth independent variable besides the book value, earnings and earnings momentum variables on which the M2 regression model is based. However, adding earnings momentum and earnings acceleration to the equity valuation process leads to a negligible improvement in the explanatory power over the basic equity valuation model M1 that includes only earnings and book value as explanatory variables. The adjusted R^2 increases from 27.24% for M1 to 27.38% for M2 and finally, to 27.46% for M3. Moreover, none of the t-scores associated with the earnings momentum and earnings acceleration variables in M2 and M3 are statistically significant. It can also be observed that the adjusted R^2 values increase from about 23% for sample data between 1999 and 2012 as shown in Table 4.2 to about 27% for sample data between 2005 and 2012 as shown in Table 4.10. This means that accounting information disclosed after 2005 appears to contain more information in explaining contemporaneous stock prices than its counterpart information before 2005. In other words, the increase in R^2 values indicates that market participants are more dependent on the accounting information when determining the market value of a firm's equity. Table 4.10 also presents the

Durbin-Watson statistics associated with each regression model. The calculation of the Durbin-Watson statistics follows our previous procedure of ranking the firm-years in terms of the profitability ratio, $q(t)$. The residuals from the ordered sequence based on the $q(t)$ ratios were then calculated for all three regression models and the Durbin-Watson statistics computed for each model separately. The Durbin-Watson statistics are all slightly below their expected value of two, thereby indicating that the residuals in the regression models vary systematically according to the level of firm profitability. We have previously noted, however, that this is an issue that can be addressed by dividing firms into one of three levels of operational efficiency. Before doing so, however, we note that the F-statistics associated with the M1, M2 and M3 regression models are all statistically significant at any reasonable level, thereby confirming that one can reject the maintained hypothesis that $R^2 = 0$ for all three regression models.

Table 4.10

Coefficient Estimates for First Order Model (M1), Second Order Model (M2) and Third Order Model (M3) for the Full-sample Data

2005-2012

Firm-Year N = 4,227

$$\mathbf{M1:} P(t) = \beta_0 + \beta_1 x(t) + \beta_2 b(t) + e(t)$$

$$\mathbf{M2:} P(t) = \beta_0 + \beta_1 x(t) + \beta_2 b(t) + \beta_3 x'(t) + e(t)$$

$$\mathbf{M3:} P(t) = \beta_0 + \beta_1 x(t) + \beta_2 b(t) + \beta_3 x'(t) + \beta_4 x''(t) + e(t)$$

Valuation Model	Model Coefficients t-statistics Listed Below Coefficients					Model Adjusted R ²	Model F-statistic & D-W Value
	β_0	β_1	β_2	β_3	β_4		
First Order Model (M1)	10.47	5.14	1.27			27.24%	F=792.27 D-W=1.83
	95.18	2.62	5.63				
Second Order Model (M2)	10.47	5.69	1.17	-0.72		27.38%	F=532.19 D-W=1.84
	95.29	2.91	6.57	-0.58			
Third Order Model (M3)	10.47	6.00	1.12	-1.43	0.40	27.46%	F=400.97 D-W=1.84
	95.35	3.17	7.29	-1.10	0.81		

White (1980) adjusted t-statistics are listed below the regression coefficients.

Variable Definitions: $b(t)$ = Book value of equity per share at the beginning of year t . It represents the book value (proportioned common equity divided by outstanding shares) at the company's fiscal year end, $(t - 1)$ (Datastream mnemonic WC05476). $x(t)$ = Earnings per share for year t . It represents the earnings for the 12 months ended the fiscal year t . Earnings per share are profit after tax, minority interest and preferred dividends but before extraordinary items (Datastream mnemonic WC05201). $x'(t) \approx x(t) - x(t - 1)$ = earnings momentum. It measures the change in earnings from year $(t - 1)$ to year t . $x''(t) \approx [x(t) - 2x(t - 1) + x(t - 2)]$ = earnings acceleration. It measures the rate of change in earnings momentum.

Finally, we also ran the condition number test in order to assess whether our regression procedures might be afflicted by problems of multi-collinearity. Here it will be recalled that a condition number above 15 signals potential problems with co-linear variables. However, the results of the condition number test, as reported in Tables 4.11, show that there is no reason to believe multi-collinearity is an issue with our regression procedures. Note in particular how the condition index amounts to 4.396 which is well within the generally accepted value of 15 at which multi-collinearity in the independent variables may become an issue.

Table 4.11 Multi-collinearity Diagnostics (Full-sample)

Model Dimension	Eigenvalue	Condition Index	Variance Proportions				
			(Constant)	Earnings	Book Value	Earnings Momentum	Earnings Acceleration
1	2.105	1	0	0.04	0	0.04	0.05
2	1.241	1.302	0	0.08	0.35	0	0.01
3	1	1.451	1	0	0	0	0
4	0.545	1.966	0	0.24	0.29	0	0.25
5	0.109	4.396	0	0.64	0.35	0.95	0.68

4.3.2.2 Descriptive Statistics and Empirical Results on Efficiency Groups from 2005 to 2012

We have previously noted how the valuation coefficients associated with a firm's earnings and the book value of its equity will change in response to changes in its operational efficiency. In other words, market participants will change their focus from certain explanatory variables in the equity valuation process to others as the firm's profitability level changes. Given this, we again conduct price-level regressions based on firms with different levels of operational efficiency - but on this occasion based on our sub-sample of firm years covering the period from 2005 until 2012. We again rank equity securities on the basis of their most recent profitability ratio:

$$q(t) = \frac{x(t)}{b(t-1)}$$

where $x(t)$ is earnings per share for year t , $b(t - 1)$ is the book value of equity per share at the end of year $(t - 1)$ and $q(t)$ measures the firm's ability to generate profits from its assets, thereby measuring its operational efficiency. In our efficiency sub-sample empirical tests, all firm-year data are assigned to three equally numerous groups. The bottom tertile is thus comprised of the $N_1 = 1,409$ firm-years with the lowest operational efficiency; the middle tertile is comprised of the $N_2 = 1,409$ firm-years with steady-state or moderate operational efficiency; while the top tertile is comprised of the $N_3 = 1,409$ firm-years with the highest level of operating efficiency.

Table 4.12 provides summary statistical information relating to the composition of the sub-sample data covering the period from 2005 until 2012 and on which our regression analysis is based. Table 4.12 shows that the mean and median of the centred book value of equity across the $N_1 = 1,409$ firm-years comprising our sub-sample of low-efficiency firms are zero and -0.09, respectively. Likewise, the standard deviation of the centred book values across our sub-sample of low efficiency firms is 1.96. Finally, the minimum centred book value in our sub-sample of low-efficiency firms is -26.25 whilst the maximum centred book value is 15.90. The descriptive statistics of the other variables summarised in Table 4.12 are to be similarly interpreted.

Table 4.12
Distributional Properties of Low-efficiency, Steady-state and High-efficiency Sub-samples
2005-2012

	x(t)	b(t)	x'(t)	x''(t)
Low-efficiency (Firm-Year $N_1 = 1,409$)				
Mean	0.00	0.00	0.00	0.00
Median	0.10	-0.09	0.05	0.05
Std. Deviation	0.73	1.96	0.85	1.20
Minimum	-21.78	-26.25	-20.41	-18.54
Maximum	5.32	15.90	6.28	9.80
Steady-state (Firm-Year $N_2 = 1,409$)				
Mean	0.00	0.00	0.00	0.00
Median	-0.03	-0.28	-0.01	0.00
Std. Deviation	0.15	1.56	0.21	0.53
Minimum	-0.94	-8.38	-2.25	-4.12
Maximum	0.95	9.63	2.47	11.19
High-efficiency (Firm-Year $N_3 = 1,409$)				
Mean	0.00	0.00	0.00	0.00
Median	-0.11	-0.32	-0.07	-0.03
Std. Deviation	0.56	1.93	0.69	1.41
Minimum	-4.09	-23.59	-6.42	-16.75
Maximum	7.90	15.32	18.67	39.26

Variable Definitions: $b(t)$ = Book value of equity per share at the beginning of year t . It represents the book value (proportioned common equity divided by outstanding shares) at the company's fiscal year end, $(t - 1)$ (Datastream mnemonic WC05476). $x(t)$ = Earnings per share for year t . It represents the earnings for the 12 months ended the fiscal year t . Earnings per share are profit after tax, minority interest and preferred dividends but before extraordinary items (Datastream mnemonic WC05201). $x'(t) \approx x(t) - x(t - 1)$ = earnings momentum. It measures the change in earnings from year $(t - 1)$ to year t . $x''(t) \approx [x(t) - 2x(t - 1) + x(t - 2)]$ = earnings acceleration. It measures the rate of change in earnings momentum.

Table 4.13 summarises the estimated coefficients and their associated t-scores for the three efficiency sub-samples covering the period from 2005 until 2012. Our empirical results show that for the M1 regression model comprising low-efficiency firms that the coefficients associated with the book value and earnings variables are both significant and positive. However, the adjusted R^2 value is only 6.55%. We then augment the M1 regression model by including earnings momentum as an additional variable (as in the M2 regression model). Moreover the M3 regression model incorporates earnings acceleration as a fourth independent variable besides the book value, earnings and earnings momentum variables on which the M2 regression model is based. However, adding earnings momentum and earnings acceleration to the equity valuation process leads to a negligible improvement in the explanatory power over the basic equity valuation model M1 which includes only earnings and book value as explanatory variables. The adjusted R^2 increases from 6.55% for M1 to 6.62% for M2 and finally, to 6.67% for M3. Moreover, none of the t-scores associated with the earnings momentum and earnings acceleration variables in M2 and M3 are statistically significant. Note also that whilst the coefficient associated with the earnings variable in the M1 regression model is highly significant, in the M2 and M3 regression models, where earnings momentum and earnings acceleration are incorporated as explanatory variables, the coefficient associated with earnings is small and statistically insignificant. It will also be observed from Table 4.5 that the coefficients associated with book value lie in the range between 0.28 and 0.29 based on sample data between 1999 and 2012. In contrast, Table 4.13 shows that the coefficients associated with book value lie in the range between 0.58 and 0.67 based on sample data between 2005 and 2012. The corresponding t-statistics increase from the range between 3.38 and 3.68 for the years covering 1999 until 2012 to the range between 4.59 and 5.06 for the years between 2005 and 2012. The results based on sample data from 2005 to 2012 are consistent with prior empirical studies which find that book value is the predominant determinant of equity values for low-efficiency firms. (Burgstahler & Dichev, 1997; Collins et al., 1999). Note here that the R^2 values for low-efficiency firms based on sample data from 2005 to 2012 are all slightly higher

than 6.5%. This contrasts with the R^2 values summarised in Table 4.5 for low-efficiency firms based on sample data from 1999 to 2012 which all hover around the 2.4% level. The increase in the coefficients associated with book value and the corresponding increase in R^2 values indicate that after 2005 book value carried more information in explaining contemporaneous stock price than its counterpart before 2005. However, the relatively low R^2 values indicate that models which simply include book value and earnings as determining variables do not provide a satisfactory explanation of contemporaneous stock price for firms in the low-efficiency classification. In Chapter 5 we will provide possible explanations as to why the R^2 values are so low for the low-efficiency group of companies.

The empirical results for the steady-state sub-sample of firms are summarised in the second panel of Table 4.13. Note how Table 4.13 shows that the coefficients associated with the book value and earnings variables are positive and highly significant across each of the M1, M2 and M3 regression models. When earnings momentum is taken into the valuation process as in the M2 regression model, it turns out to have a positive and highly significant impact on the market value of equity with an estimated regression (that is, valuation) coefficient of 2.78 and corresponding t-score of 3.98. Recall here that earnings momentum also has a highly significant and positive association with the market value of equity for firms with moderate efficiency in our full sample covering the period from 1999 until 2012. We then go on to augment M2 by incorporating earnings acceleration into the M3 regression model. In the M3 regression model earnings momentum still exhibits a positive and highly significant association with the market value of equity with an estimated valuation coefficient of 3.35 and corresponding t-score amounting to 4.10. However, the coefficient associated with earnings acceleration, -0.36, is small and insignificant with a t-score amounting to -1.41. Here it needs to be emphasised, however, that whilst the M2 and M3 regression models suggest that the earnings momentum variable has a significant impact on the market value of equity for the steady-state firm-years comprising our sample, it is nonetheless the case that there is only a trivial increase in the R^2 value as we move from the M1 regression model (where $R^2 = 23.25\%$) to the M2 regression model

(where $R^2 = 24.48\%$) and finally to the M3 regression model (where $R^2 = 24.50\%$). Thus, the inclusion of earnings momentum as a component of the equity valuation model does not appear to bring any particular advantage over the more parsimonious M1 model based on earnings and the book value of equity alone. Consistent with the empirical results summarised in Table 4.5 based on sample data between 1999 and 2012, there is also a considerable increase in the coefficients associated with earnings from the low-efficiency group (between -0.18 and 0.45) to those associated with the steady-state efficiency group (between 9.68 and 10.22). Moreover, as with the results summarised in Table 4.5 for the steady-state group of firms, the coefficients associated with earnings summarised in Table 4.13 for steady-state firms covering the period from 2005 until 2012 are also about nine times those associated with book value.

We now turn the focus of our attention to the high-efficiency sub-sample of firms. The results summarised in the third panel of Table 4.13 show that neither earnings momentum nor earnings acceleration contribute significantly to the equity values comprising the high-efficiency sub-sample of firms. In particular, the coefficient on the earnings momentum variable in M3 is -0.32 with a t-score of -0.32. Similarly, the coefficient on the earnings acceleration variable in M3 is 0.57 with a corresponding t-score of 1.27. Moreover, the adjusted R^2 values associated with the three regression models in the high-efficiency classification show that neither earnings momentum nor earnings acceleration add much in the way of explanatory power to the simple equity valuation model, M1, based on the earnings and book value variables alone. Here there is only a trivial increase in the value of the R^2 statistic as one moves from the M1 regression model (where $R^2 = 42.69\%$) to the M2 regression model (where $R^2 = 42.76\%$) and finally, to the M3 regression model (where $R^2 = 42.87\%$). Of more significance, however, is that our empirical results show that earnings has a more compelling role to play than book value in the determination of the equity values of the high-efficiency sub-sample of firms. The valuation coefficients associated with the earnings variable are all large with t-statistics that are highly significant in all three regression models. In contrast, the coefficients associated with the book value variable are all small with

corresponding t-scores that indicate that the book value variable has an inconsequential impact on the market value of equity for the high-efficiency classification of firms. This is consistent with prior empirical work which finds that for high-efficiency firms earnings is the predominant determinant of equity value (Burgstahler & Dichev, 1997; Collins et al., 1999; Zhang & Chen, 2000). However, it will be observed from Table 4.5 that the coefficients associated with the earnings variable for high-efficiency firms decrease from the range between 16.53 and 16.91 based on sample data between 1999 and 2012 to the range between 13.21 and 13.82 based on sample data between 2005 and 2012 as summarised in Table 4.13. The corresponding t-statistics decrease from the range between 6.82 and 7.09 for high-efficiency firms covering the period from 1999 until 2012 to the range between 4.34 and 4.60 for high-efficiency firms covering the period from 2005 until 2012. Note also that the R^2 values for models in the high-efficiency classification based on sample data from 2005 to 2012 decrease to about 42% in comparison with the R^2 values of around 51% for the models based on high-efficiency firms covering the period from 1999 to 2012 as shown in Table 4.5. The decrease in both the earnings coefficients and R^2 values indicates that after 2005, the stock prices of high-efficiency firms are less dependent on earnings information in the equity valuation process.

Table 4.13 also presents the Durbin-Watson statistics associated with each regression model. The calculation of the Durbin-Watson statistics follows our previous procedure of ranking the firm-years in terms of the profitability ratio, $q(t)$. The residuals from the ordered sequence based on the $q(t)$ ratios were then calculated for all three regression models and the Durbin-Watson statistics are computed for each model separately. For all three regression models the Durbin-Watson statistics cluster around their expected value of two, thereby confirming that there are no significant problems with autocorrelated residuals in our regression models. Thus, classifying firms into one of three groups based on their operational efficiency addresses the issue of serial correlation that emerged with our regression procedures based on the pooled data. Moreover, all F-statistics are

statistically significant at any reasonable level thereby confirming that one can reject the maintained hypothesis that $R^2 = 0$ for all three regression models.

As a final exercise we also ran the condition number test in order to assess whether our regression procedures might be afflicted by problems of multi-collinearity. Here it will be recalled that a condition number above 15 signals potential problems with co-linear variables. However, the results of the condition number test, as reported in Tables 4.14 through Table 4.16, show that there is no reason to believe multi-collinearity is an issue with our regression procedures. Note in particular how the largest condition index across the three tables amounts to 7.348 which is well within the generally accepted value of 15 at which multi-collinearity in the independent variables may become an issue.

Table 4.13

**Coefficients Estimate for First Order Model (M1), Second Order Model (M2) and Third Order Model (M3) for Low-efficiency,
Steady--state Efficiency and High-efficiency Sub-samples
2005-2012**

$$\mathbf{M1:} P(t) = \beta_0 + \beta_1 x(t) + \beta_2 b(t) + e(t)$$

$$\mathbf{M2:} P(t) = \beta_0 + \beta_1 x(t) + \beta_2 b(t) + \beta_3 x'(t) + e(t)$$

$$\mathbf{M3:} P(t) = \beta_0 + \beta_1 x(t) + \beta_2 b(t) + \beta_3 x'(t) + \beta_4 x''(t) + e(t)$$

Valuation Model	Model Coefficients t-statistics Listed Below Coefficient					Model Adjusted R ²	Model F-statistic & D-W Value
	β_0	β_1	β_2	β_3	β_4		
Low-efficiency (Firm-Year N ₁ = 1,409) First Order Model (M1)	8.07	0.45	0.58			6.55%	F=50.352 D-W=1.99
	69.16	2.07	4.59				
Second Order Model (M2)	8.07	0.05	0.63	0.41		6.62%	F=34.26 D-W=1.99
	69.21	0.13	4.72	1.19			
Third Order Model (M3)	8.07	-0.18	0.67	0.89	-0.24	6.67%	F=26.14 D-W=1.99
	69.25	-0.33	5.06	1.18	-0.75		

Steady-state (Firm-Year $N_2 = 1,409$) First Order Model (M1)	9.66	10.22	0.65			23.25%	F=214.29
	79.57	4.56	3.22				D-W=1.91
Second Order Model (M2)	9.66	9.85	0.75	2.78		24.48%	F=153.10
	80.24	4.42	3.62	3.98			D-W=1.90
Third Order Model (M3)	9.66	9.68	0.76	3.35	-0.36	24.50%	F=115.21
	80.28	4.31	3.66	4.10	-1.41		D-W=1.90
High-efficiency (Firm-Year $N_3 = 1,409$) First Order Model (M1)	13.69	13.82	0.11			42.69%	F=525.31
	56.09	4.60	0.24				D-W=1.93
Second Order Model (M2)	13.69	13.21	0.28	0.69		42.76%	F=351.58
	56.14	4.34	0.78	0.56			D-W=1.93
Third Order Model (M3)	13.69	13.56	0.24	-0.32	0.57	42.87%	F=265.12
	56.21	4.41	0.64	-0.32	1.27		D-W=1.93

White (1980) adjusted t-statistics are listed below the regression coefficients.

Variable Definitions: $b(t)$ = Book value of equity per share at the beginning of year t . It represents the book value (proportioned common equity divided by outstanding shares) at the company's fiscal year end, $(t - 1)$ (Datastream mnemonic WC05476). $x(t)$ = Earnings per share for year t . It represents the earnings for the 12 months ended the fiscal year t . Earnings per share are profit after tax, minority interest and preferred dividends but before extraordinary items (Datastream mnemonic WC05201). $x'(t) \approx x(t) - x(t - 1)$ = earnings momentum. It measures the change in earnings from year $(t - 1)$ to year t . $x''(t) \approx [x(t) - 2x(t - 1) + x(t - 2)]$ = earnings acceleration. It measures the rate of change in earnings momentum.

Table 4.14 Multi-collinearity Diagnostics (Low-efficiency Sub-sample)

Model Dimension	Eigenvalue	Condition Index	Variance Proportions				
			(Constant)	Earnings	Book Value	Earnings Momentum	Earnings Acceleration
1	2.363	1	0.01	0.02	0.01	0.01	0.02
2	1.375	1.311	0.24	0.02	0.16	0	0
3	0.722	1.809	0.3	0	0.44	0	0.03
4	0.497	2.181	0.39	0.22	0	0	0.08
5	0.044	7.348	0.05	0.73	0.4	0.99	0.87

Table 4.15 Multi-collinearity Diagnostics (Steady-state Sub-sample)

Model Dimension	Eigenvalue	Condition Index	Variance Proportions				
			(Constant)	Earnings	Book Value	Earnings Momentum	Earnings Acceleration
1	2.101	1	0	0.03	0.03	0.04	0.04
2	1.561	1.16	0	0.03	0.03	0.07	0.07
3	1	1.449	1	0	0	0	0
4	0.218	3.105	0	0.04	0.05	0.76	0.78
5	0.12	4.18	0	0.89	0.89	0.14	0.12

Table 4.16 Multi-collinearity Diagnostics (High-efficiency Sub-sample)

Model Dimension	Eigenvalue	Condition Index	Variance Proportions				
			(Constant)	Earnings	Book Value	Earnings Momentum	Earnings Acceleration
1	1.912	1	0	0.07	0.06	0.06	0.03
2	1.3	1.213	0	0.01	0.07	0.13	0.28
3	1	1.383	1	0	0	0	0
4	0.613	1.766	0	0.01	0.06	0.39	0.67
5	0.174	3.311	0	0.91	0.81	0.43	0.02

4.4 Conclusion

The main aim of this chapter has been to estimate the impact that earnings momentum and earnings acceleration have on the market value of equity for firms listed on the SSE. Our empirical analysis covers the period from 1999 until 2012 in the first instance. However, since the early part of this period was characterised by a depressed SSE and poor investor protection laws, we also replicate our empirical analysis over the shorter period from 2005 until 2012. During this latter period the SSE had returned to more buoyant trading conditions and investor protection laws had been considerably strengthened. Our empirical analysis is based on the equity valuation model developed by Davidson and Tippett (2012) which shows that if a firm's investment opportunity set can be stated in terms of a third order system of stochastic differential equations then both earnings momentum and earnings acceleration can have a significant impact on the market value of a firm's equity.

We then move on to describe the variables and the dataset used in our empirical analysis. Our empirical tests consist of two parts. In the first part of our empirical analysis covering pooled data over period from 1999 until 2012, our results show that neither earnings momentum nor earnings acceleration exhibit any impact on the market value of equity. However, when we divide the pooled data into three equally numerous groups based on each firm's operational efficiency, we find that for steady-state firms the t-score associated with earnings momentum becomes significant. This contrasts with the t-scores associated with the earnings momentum variable for low-efficiency and high-efficiency firms, both of which are insignificantly different from zero. Moreover, the inclusion of earnings momentum in our regression models only adds trivial explanatory power to the parsimonious regression model based on earnings and book value alone. The coefficients associated with earnings acceleration in all three efficiency level regressions are insignificantly different from zero. This shows that earnings acceleration does not appear to have much of an impact on equity values.

It has been argued that the absence of earnings momentum effects might be due to the comparatively poor protection provided to outside shareholders by the legal and regulatory system in China. We note, in particular, how beginning at the end of the 1990's the Chinese government implemented a vigorous reform programme under which the security laws and regulations governing the operation of China's capital markets were brought more into line with those operating in western economies. The reform agenda relating to these laws was largely completed between 2005 and 2006. Given this, we apply the same regression procedures as we apply to the sample data over the period from 1999 until 2012 to the sample data between the period 2005 and 2012 in order to test whether earnings momentum and earnings acceleration have any impact on equity values when investor protection laws were much more rigorous than in previous years. The empirical results based on the pooled sample data for the period from 2005 until 2012 show, again, that neither earnings momentum nor earnings acceleration exhibit any value relevance to the market value of equity for firms listed on the SSE. We then divide our pooled data into three equally numerous groups based on each firm's operational efficiency. The empirical results show that only the t-scores associated with the earnings momentum variable for steady-state firms turns out to be significant. However, again, the inclusion of earnings momentum only leads to a trivial increase in the explanatory power of our regression models when compared to the parsimonious regression model based on earnings and book value alone. Our overall results show that for firms listed on the SSE neither earnings momentum nor earnings acceleration have a significant impact on equity values in general - although there is some evidence for a very narrow group of firms that earnings momentum can have a small impact on their equity values. Moreover, our empirical results based on sample data from the period 1999 to 2012 and those based on sample data from the period 2005 to 2012 are generally consistent.

There are two possible reasons why earnings momentum and earnings acceleration appear to have very little impact on the equity values of firms listed on the SSE. First, although the Chinese government has introduced market-oriented laws, policies and other measures to improve the fairness, openness and efficiency of Chinese capital markets, the enforcement of these laws has been poor and

ineffective. The mere existence of laws and regulations is not sufficient to insure that investors will be protected from fraudulent activities. Here enforcement is vital. The weak enforcement of the laws and regulations put onto the statute book by the Chinese authorities is evidenced by the Corruption Perceptions Index (CPI)¹⁶. In 2012 China with a score of 39 on this Index ranked 80. This compares with a Corruption Index score of 74 and a rank of 17 for the UK and the US with score of 73 and a rank of 19. The Chinese ranking of 80 is out of place with its fast growing economy and indicates the serious nature of the problems that have arisen with the poor enforcement of China's securities laws and regulations. Although there has been a crackdown on insider trading in China in recent years, the laws and regulations relating to insider trading in China are widely considered to be far from effective (Huang, 2007). Moreover, the poor enforcement of China's laws and regulations in this area has been of long-standing international concern. The root cause of these problems can be traced to the structure of China's society and economic system. The current social structure and economic system unavoidably create incentives and social forces that distort the fairness, openness and efficiency of Chinese capital markets. Given this, it makes little difference as to who is responsible for the enforcement of investor protection laws in China. As long as the basic social and economic structure is maintained, the incentives faced by Chinese regulators and law makers to distort the fairness, openness and efficiency of Chinese capital markets will remain. Therefore, one cannot expect regulators and lawmakers, whoever they may be, to act differently in either the setting up of a sensible system of investor protection laws and regulations or in the enforcement of such laws and regulations. In the long run, the tolerance or even stimulation of illegal activities will create a significant obstacle to the development of China's capital markets. This will also reduce investor confidence and participation which, in recent years, the Chinese government has been trying hard to sustain and improve.

The second potential reason why earnings momentum and earnings acceleration have had such a minimal impact on the market value of equity stocks listed on the

¹⁶ The Corruption Perceptions Index can be accessed at the following web address:
<http://www.transparency.org/cpi2012/results>

SSE is that the investment opportunity sets of firms simply cannot be expressed in terms of a third order system of stochastic differential equations. As noted in the empirical results based on the efficiency sub-samples, book value carries more weight than earnings in explaining the market value of equity for firms listed on the SSE with low operational efficiency. In contrast, earnings is the principal determining factor explaining equity values for firms listed on the SSE with high operational efficiency. This suggests that the relationship between the market value of equity and its determining variables is much more complicated than the simple linear models on which the empirical analysis conducted in this chapter is based. Moreover, the regression models on which our empirical analysis is based all originate from the Ohlson (1995) model. Here it will be recalled that the Ohlson (1995) model assumes that a firm is indefinitely constrained to operate within its current investment opportunity set. This assumption is unrealistic as firms always have opportunities to change their existing operations. These opportunities give rise to the adaptation value of equity which, in earlier chapters, we show can make a significant contribution to the overall market value of a firm's equity. This adaptation value in turn makes the relationship between the market value of a firm's equity and its accounting variables non-linear. Hence, an important pitfall in the regression models we apply in this chapter is that they do not take account of the adaptation value of equity and the non-linearities which it induces between the market value of a firm's equity and its determining variables. Given this, the purpose of our next chapter is to assess whether the inclusion of the non-linear terms on which the adaptation value of equity is based can provide a more complete description of the relationship between equity prices and their determining variables.

Chapter 5

Methodology and Empirical Analysis on Non-linearities

5.1 Introduction

This chapter is the second that summarises the empirical results relating to the equity valuation models outlined in Chapter 2 and Chapter 3, and provides an important part of the empirical results of this dissertation. In particular, this chapter assesses the form and magnitude of the non-linear relationship which exists between the market value of equity and published accounting information for firms listed on the Shanghai Stock Exchange (SSE) and aims to highlight the importance of real option value in explaining the market value of equity for both pooled sample firms and sample firms with different operational efficiencies. As in Chapter 4, the data in this chapter consists of a large sample of firms listed on the SSE covering the period from 1999 until 2012.

Empirical work in this area has invariably been based on the assumption of a linear relationship between the market value of a firm's equity and the information appearing in its published financial statements. However, in recent years growing international evidence has emerged which shows that there is a highly non-linear relationship between market value of equity and its determining variables. The empirical evidence is largely compatible with the hypothesis that firms possess strategic and operational (real) options that provide them with the potential to modify or even abandon their existing investment opportunity sets. Moreover, these options can make a significant contribution to the overall market value of equity. This in turn will mean that there will have to be a non-linear relationship between the market value of a firm's equity and its determining variables. Given this, empirical studies based on simple linear regression models which fail to encompass the non-linearity arising from real option value will more than likely lead to a mis-specified and biased account of the relationship between equity values and the information appearing in published financial statements. Moreover, it is all but inevitable that investment and policy decisions based on these mis-

specified linear models will lead to serious misallocation of resources and flawed policy decisions. It is for this reason that the purpose of this chapter is to make an empirical assessment of the form and magnitude of the non-linear relationships which exist between the market value of equity and their determining variables for firms listed on the SSE.

The rest of the chapter is organised as follows: section 5.2 offers a summary of the essential characteristics of the benchmark model on which the empirical analysis is based; namely, the Davidson and Tippett (2012) model which incorporates real option value as a crucial element of the overall market value of equity. This section also shows how the Davidson and Tippett (2012) equity valuation model is empirically implemented. Section 5.3 consists of two sub-sections. The first subsection defines the variables used in this empirical analysis and provides basic descriptive statistics pertaining to the pooled sample data covering the period from 1999 to 2012. It also summarises the empirical results obtained from applying the linear models normally encountered in the literature to data from the SSE, as well as the empirical results obtained from applying the SSE data to the benchmark non-linear equity valuation model developed in previous chapters. The second subsection classifies the pooled SSE data employed in this empirical analysis into three efficiency sub-samples; namely, a low-efficiency group, a steady-state efficiency group and a high-efficiency group. Summary of statistical information is then provided for each efficiency sub-sample before re-estimating the parameters generated by the linear and non-linear equity valuation models for each of the three efficiency groups. This permits an assessment of the contribution that the non-linear equity valuation terms make to the overall market value of equity for firms with different operational efficiencies. The empirical results are consistent with the real option hypothesis that there is a non-linear relationship between market value of equity and its determining variables for the pooled sample data and also, for the low-efficiency and high-efficiency sub-sample data. However, for firms in the steady-state efficiency classification the relationship between the market value of equity and its determining variables is broadly linear.

Unfortunately, there are significant econometric problems arising from co-linear determining variables with the full Davidson and Tippett (2012) non-linear equity valuation model; and so all regressions applied in this section are based on a reduced form interpretation of the original benchmark non-linear equity valuation model. Although dropping independent variables from the original model effectively addresses these multi-collinearity issues, excluding variables that actually belong to the benchmark model raises issues of omitted variables bias, and also reduces the ability to assess the impact that real option value can have on the overall market value of a firm's equity. Moreover, the explanatory power generated by the reduced form models when applied to low-efficiency sub-sample data is low in comparison to its counterparts based on the pooled sample and steady-state and high-efficiency subsamples. Therefore, section 5.4 offers a discussion of some possible explanations for the low R^2 values generated by the reduced form valuation models applied to the low-efficiency sub-sample of firms. Then section 5.5 addresses the multi-collinearities problem without losing any of the information embedded in the original determining variables by basing our non-linear equity valuation models on the latent vectors obtained from a Principle Components Analysis of the original determining variables. Section 5.6 concludes this chapter.

5.2 Equity Valuation Model Incorporating Real Option Value¹⁷

It has previously been noted (as in section 3.4 of Chapter 3) how Ashton et al. (2003) have developed an equity valuation model based on the assumption that the market value of a firm's equity, $P(t)$, consists of two components. The first is termed the recursion value of equity, $\eta(t)$, which is defined as the present value of future dividends the firm is expected to pay, given that it is constrained to operate indefinitely within its existing investment opportunity set. Section 2.4 noted that Ohlson (1995) has shown that the recursion value of equity can be expressed in terms of a linear combination of the book value of equity, $b(t)$, the abnormal earnings, $a(t)$, and the other information variable, $v(t)$, which captures all the

¹⁷ The Appendix to this chapter contains a much more detailed exposition of the mathematics that lies behind the non-linear equity valuation model developed here.

information relevant to the value of a firm's equity that has not, as yet, been incorporated into the firm's accounting records. In particular, Ohlson (1995) shows that the present value of the dividends a firm is expected to pay may be expressed in terms of these variables through the following formula:

$$\eta(t) = b(t) + \frac{(i - c_{22})a(t)}{(i - c_{11})(i - c_{22}) - c_{12}c_{21}} + \frac{c_{12}v(t)}{(i - c_{11})(i - c_{22}) - c_{12}c_{21}} \quad (5.1)$$

Here c_{11} , c_{12} , c_{21} and c_{22} are the structural coefficients associated with the firm's investment opportunity set (as defined in section 2.4 of Chapter 2). However, it has also been noted that the recursion value of equity provides only a partial explanation of the market value of a firm's equity. There is a second component of equity value comprised of the real option (or adaptation) value associated with a firm's ability to change or modify its existing investment opportunity set. Ashton et al. (2003, p. 240) show that when recursion value evolves in terms of a continuous time branching process and the firm possesses the ability to change or even abandon its existing investment opportunity set, then the market value of the firm's equity may be stated in terms of the following formula:

$$P(\eta) = \eta + \frac{P(0)}{2} \int_{-1}^1 \exp\left(\frac{-2\theta\eta}{1+z}\right) dz \quad (5.2)$$

Here $\theta = \frac{2i}{\zeta^2}$ is a measure of the relative stability with which the recursion value of equity grows over time, i is the cost of equity capital and ζ^2 is the variance parameter associated with the white noise term in the recursion value of equity.¹⁸ The first term, η , on the right-hand side of the above equation is the recursion value

¹⁸ See equation (3.2) of Chapter 3 and the surrounding discussion for further details about ζ^2 . We have previously noted (as in section 3.4.1) that Ataullah, et al., (2006, p. 255) provide empirical evidence relating to the U.K. economy which shows that the stability parameter varies from $\theta = 2.9619$ for the Information Technology, Non-Cyclical Consumer, Non-Cyclical Services and Resources industrial classification; to $\theta = 4.4787$ for the Basic Industries, General Industrials and Utilities industrial classification; to $\theta = 7.9737$ for the Cyclical Services Industrial classification; to $\theta = 8.3093$ for the Cyclical Consumer and Financials industrial classification.

of equity or alternatively, the Ohlson (1995) value as given by equation (5.1). The

second term, $\frac{P(0)}{2} \int_{-1}^1 \exp\left(\frac{-2\theta\eta}{1+z}\right) dz$, captures the real option value, and in turn leads

to the non-linearities that arise between the market value of equity and the information recorded in the firm's financial statements. Here $P(0)$ denotes the value of the firm's adaptation options when the recursion value of equity, η , falls away to nothing.

There are difficult econometric issues associated with the estimation of the above equity valuation model in its unreduced form. Given this, Davidson and Tippett (2012, p. 237) expand the above equity valuation function in terms of an infinite power series based on the Laguerre polynomials; namely:

$$P(\eta) = \sum_{m=0}^{\infty} \alpha_m L_m(\eta) \quad (5.3)$$

where the α_m is the “Fourier-Laguerre” coefficient associated with the m^{th} order Laguerre polynomial, $L_m(\eta)$. The first two Laguerre polynomials are $L_0(\eta) = 1$ and $L_1(\eta) = 1 - \eta$. By implementing the following recursion formula:

$$mL_m(\eta) = (2m - 1 - \eta)L_{m-1}(\eta) - (m - 1)L_{m-2}(\eta) \quad (5.4)$$

where $m \geq 2$, the higher-order Laguerre polynomials can be determined. Here it is also assumed, without loss of generality, that $P(0) = 1$ so that when the recursion value of a firm's equity, η , falls away to nothing then its adaptation value will assume a unit value. If one then follows the procedures articulated in Davidson and Tippett (2012, pp. 237-239) it can be shown that the Fourier coefficient, α_m , is determined from the following equation:

$$\alpha_m = \frac{\theta(1 + \theta)^m - (m + \theta)\theta^m}{m(m - 1)(1 + \theta)^m} \quad (5.5)$$

Substituting equations (5.4) and (5.5) into equation (5.3), shows that the market value of a firm's equity will have the following power series representation (Davidson & Tippett, 2012, p. 239):

$$P(\eta) = \sum_{m=0}^{\infty} \alpha_m L_m(\eta) =$$

$$[\theta \log\left(\frac{\theta}{1+\theta}\right) + 2] - \left[1 + \frac{\theta}{1+\theta} + \theta \log\left(\frac{\theta}{1+\theta}\right)\right][1 - \eta] + \frac{1}{4} \cdot \frac{\theta}{(1+\theta)^2} [\eta^2 - 4\eta + 2] + \text{---}$$

(5.6)

Now one can substitute equation (5.1) into the above expression and thereby obtain a third order approximation for the market value of equity in terms of the book value of the firm's equity and its earnings, namely:

$$P(t) = \beta_0 + \beta_1 x(t) + \beta_2 b(t) + \beta_3 b^2(t) + \beta_4 b(t)x(t) + \beta_5 x^2(t) +$$

$$\beta_6 b^3(t) + \beta_7 b^2(t)x(t) + \beta_8 b(t)x^2(t) + \beta_9 x^3(t) + e_3(t)$$

(5.7)

where the β_j are the valuation coefficients associated with the polynomial terms and $e_3(t)$ is an error term that captures all components of the infinite series expansion that have been omitted from equation (5.7). The following empirical analysis will be based on this basic valuation model. The non-linear effects are captured by the squared earnings term, $x^2(t)$, the squared book value term, $b^2(t)$, the cubic earnings term, $x^3(t)$, the cubic book value term, $b^3(t)$, and the cross-product terms; namely, $b(t)x(t)$, $b^2(t)x(t)$ and $b(t)x^2(t)$. Here it will be noted that the cross-product terms in the regression model, equation (5.7), reflect the interaction effects between earnings, $x(t)$ and book value, $b(t)$. Moreover, the following linear pricing model is applied by employing a first order power series approximation for the Ashton et al. (2003) equity valuation model; namely:

$$P(t) = \beta_0 + \beta_1 x(t) + \beta_2 b(t) + e_1(t)$$

(5.8)

where the β_j are the valuation coefficients associated with earnings and book value and $e_1(t)$ is an error term that captures all components of the infinite series expansion for equation (5.6) that have not been included in equation (5.8). Before I summarise the empirical results obtained from applying the regression models (5.7) and (5.8), a detailed specification of the empirical data on which our regression procedures are based will first be provided.

5.3 Descriptive Statistics and Empirical Results

5.3.1 Descriptive Statistics and Empirical Results on Pooled Data

The sample data are comprised of $N=9,209$ firm-year observations from the SSE and are drawn from the Datastream database. These data include all industrial groupings listed on the SSE and covers the period from 1999 until 2012. The reasons for the period from 1999 until 2012 over which our empirical analysis is conducted are summarised in section 4.3 of Chapter 4.

The dependent variable and the independent variables used in the empirical analysis summarised in this chapter have previously been defined in section 4.3 of Chapter 4. All listed Chinese firms have the same fiscal year-end; namely, 31 December of each year. Their annual reports have to be published by 30 April of the following year. To capture the relationship between the accounting variables used in the regression analysis and the market value of equity, it is assumed that the closing share price on 30 April each year fully reflects the market's reaction to the assimilated information contained in the financial reports covering the fiscal year ending up until 31 December of the previous year. Given this, the market value of equity, $P(t)$, which is the dependent variable in the regression model, is defined as the stock price on 30 April in the year following the balance sheet date for the firm's published financial statements. The market value of equity is adjusted for capital issues such as stock splits and dividend payments during the year (Datastream Datatype (P)).

Independent variables are comprised of the book value of equity, $b(t)$, earnings, $x(t)$, squared earnings, $x^2(t)$, squared book value, $b^2(t)$, cubic earnings, $x^3(t)$, cubic book value, $b^3(t)$, and the cross-product terms; namely, $b(t)x(t)$, $b^2(t)x(t)$, and $b(t)x^2(t)$. As in previous chapters $b(t)$ represents the book value of equity per share at the beginning of year t ; that is at time $(t - 1)$. It represents the book value (proportioned common equity divided by outstanding shares) at the company's fiscal year end, $(t - 1)$ (Datastream mnemonic WC05476). The reason that the book value disclosed at the end of year $(t - 1)$ is used rather than book value disclosed at the end of year t (as explained in section 4.3 of Chapter 4) is that the latter includes earnings for year t as a component (Burgstahler & Dichev, 1997, p. 195). Moreover, $x(t)$ is earnings per share disclosed for year t . It represents the earnings for the 12 months ended the fiscal year t . Earnings per share is profit after tax, minority interest and preferred dividends but before extraordinary items (Datastream mnemonic WC05201).

The data for the book value of equity are collected as far back as the year 1999; the data for earnings are collected from the year 2000 onwards, whilst the data for the market value of equity are collected from the year 2001 onwards. Firm-year data are excluded from our empirical analysis if the market value of equity, book value or earnings variables required for the regression analysis are missing or are not available. Firm-year data with a zero book value are also excluded, as firm efficiency is assessed in terms of the ratio of the firm's earnings to the book value of its equity. After eliminating 219 firm-years of missing data and/or firm-year data with a zero book value, the regression procedures are based on a total of $N = 9,209$ firm-year observations. Moreover, it is well known that the independent variables in polynomial regression models are very likely to be correlated and this will mean that parameter estimation will be afflicted by issues of multi-collinearity (Ofir & Khuri, 1986). Cohen, et al. (2003, p. 264) show that the use of centred data substantially reduces the adverse impact of non-essential multi-collinearity on parameter estimates and their associated t-scores. Given this, all the estimation procedures are based on centred (that is, mean-adjusted) data.

Table 5.1 provides summary statistical information relating to the data on which the regression procedures are based. This table shows that the mean and median of the centred book value of equity across the $N = 9,209$ firm-years comprising our sample are zero and -0.23, respectively. Likewise, the standard deviation of the centred book values across the sample data is 1.80. Finally, the minimum centred book value in our sample is -26.19 whilst the maximum centred book value is 42.16. The descriptive statistics associated with the other variables summarised in Table 5.1 are to be similarly interpreted. The difference between the median value of earnings (book value) and the mean value of earnings (book value) is very small and this indicates that the data do not suffer from serious issues of skewness.

Table 5.1
Distributional Properties of Full-sample Data
Firm-Year N = 9,209

	$x(t)$	$b(t)$	$b^2(t)$	$x(t)b(t)$	$x^2(t)$	$b^3(t)$	$b^2(t)x(t)$	$b(t)x^2(t)$	$x^3(t)$
Mean	0.00	0.00	3.26	0.07	0.34	35.23	-3.80	3.32	-3.76
Median	-0.03	-0.23	0.62	0.03	0.01	-0.01	0.00	0.00	0.00
Std. Deviation	0.57	1.80	38.63	10.37	9.89	1448.18	336.56	266.84	260.12
Minimum	-28.24	-26.12	0.00	-901.50	0.00	-17969.24	-28779.00	-497.40	-22519.66
Maximum	8.29	42.16	177.68	141.53	797.46	74951.40	4707.94	25457.67	570.69

Variable Definitions: $b(t)$ = Book value of equity per share at the beginning of year t . It represents the book value (proportioned common equity divided by outstanding shares) at the company's fiscal year end, $(t - 1)$ (Datastream mnemonic WC05476). $x(t)$ = Earnings per share for year t . It represents the earnings for the 12 months ended the fiscal year t . Earnings per share is profit after tax, minority interest and preferred dividends but before extraordinary items (Datastream mnemonic WC05201). All descriptive statistics are based on centred data.

The empirical analysis commences by applying the condition number test to the determining variables summarised in Table 5.1 in order to assess whether these regression procedures might be afflicted by problems of multi-collinearity. Here it will be recalled that a large condition number (>15) indicates that linear dependencies exist among our determining variables. When there is evidence of co-linear determining variables effective remedial measures, such as adding new data, omitting variables, principal component analysis etc., have been suggested in the literature. The potential effectiveness of each of these remedial measures is now examined.

Adding new data: Adding new data is probably the most pervasive method used to alleviate multi-collinearity issues. It can be noted that within the accounting structural system, accounting variables (e.g. book value, earnings, etc.) interact with each other and this in turn means that there are inherent correlations among accounting variables. Thus, as the collinearity is inherent in the accounting system adding new data may not necessarily address the multi-collinearity problem (Ofir & Khuri, 1986). Moreover, given that China's first *Securities Law* did not come into force until 1999, it is highly unlikely that financial information disclosed prior to 1999 will have the same impact on equity prices as financial information disclosed after the *Securities Law* came into force. These considerations will mean that adding new data would not be an ideal remedy for the multi-collinearity issues arising from the data employed in our empirical analysis.

Omitting variables: the first method used in this empirical analysis to address the multi-collinearity issue is the omission of highly co-linear determining variables. Although this procedure is highly subjective, it is widely implemented in empirical studies (Ofir & Khuri, 1986). Given this, the first part of the empirical analysis will be based on reduced form interpretations of the benchmark non-linear equity valuation model that omit any highly co-linear independent variables.

Principal Component Analysis: Principal component analysis is one of the most popular multivariate statistical techniques that have been used in accounting and finance research. Its main advantage is that it extracts the eigenvalues and

corresponding eigenvectors of a given variance-covariance matrix and then uses them to define a new set of independent variables that are mutually orthogonal (Ofir & Khuri, 1986). These orthogonal variables, which are all uncorrelated with each other, are then used as independent variables in the regression analysis. The major difficulty with this technique is that it is often difficult to understand what the orthogonally defined independent variables actually represent. I will apply principal components analysis to the sample data in the second part of my empirical testing procedures.

Having examined the potential approaches that may be used to address the multicollinearity issue, our empirical analysis commences by applying the following reduced form interpretation of the original benchmark model (as given by equation (5.7)) to the pooled sample of data:

$$P(\eta) = \beta_0 + \beta_1 x(t) + \beta_2 b(t) + \beta_3 b^2(t) + \beta_4 x^2(t) + \beta_5 b^3(t) + \beta_6 x^3(t) + e_2(t) \quad (5.9)$$

Here, as previously, $b(t)$ is the book value of equity, $x(t)$ is earnings and the β_j are the valuation coefficients associated with each element of our reduced form valuation model. Table 5.2 contains the estimates of the coefficients, the associated t-scores, F-statistics, the Durbin-Watson values generated by the regression model (5.9) and the simple linear equity valuation regression model (5.8). White's (1980) heteroskedastic-consistent covariance matrix estimation procedure is used in all regressions to correct the estimates for any unknown forms of heteroskedasticity. All regressions are based on the $N = 9,209$ firm-year observations comprising our sample. Student t-statistics are listed below all estimates of the regression coefficients.

Table 5.2

Coefficient Estimates for Linear Model (M1), Reduced High Order Approximation Model (M2) for the Full-sample Data

Firm-Year N = 9,209

$$\mathbf{M1:} P(t) = \beta_0 + \beta_1 x(t) + \beta_2 b(t) + e_1(t)$$

$$\mathbf{M2:} P(t) = \beta_0 + \beta_1 x(t) + \beta_2 b(t) + \beta_3 b^2(t) + \beta_4 b(t)x(t) + \beta_5 x^2(t) + \beta_6 b^3(t) + \beta_7 b^2(t)x(t) + \beta_8 b(t)x^2(t) + \beta_9 x^3(t) + e_2(t)$$

Valuation Model	Model Coefficients t-statistics Listed Below Coefficients										Model Adjusted R ²	Model F-statistic & D-W Value
	β_0	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9		
Model (M1)	8.27 128.30	4.09 3.83	1.23 6.55								22.53%	F=1339.74 DW=1.821
Reduced High Order Approximation (M2)	7.98 126.10	6.51 10.42	1.22 12.60	0.03 2.48	- -	1.16 4.98	-0.00 -5.94	- -	- -	0.04 3.22	38.15%	F=947.682 DW=1.869

White (1980) adjusted t-statistics are listed below the coefficients.

Variable Definitions: b(t) = Book value of equity per share at the beginning of year t. It represents the book value (proportioned common equity divided by outstanding shares) at the company's fiscal year end, (t - 1) (Datastream mnemonic WC05476). x(t) = Earnings per share for year t. It represents the earnings for the 12 months ended the fiscal year t. Earnings per share is profit after tax, minority interest and preferred dividends but before extraordinary items (Datastream mnemonic WC05201).

The empirical results show that for the M1 and M2 regression specifications the coefficients associated with the book value variable, $b(t)$, and the earnings variable, $x(t)$, are both positive and highly significant. However, when the simple linear regression model, M1, is augmented to include the higher order terms as in the M2 regression specification, the coefficients associated with the book value variable decline slightly from $\beta_2 = 1.23$ for the linear model M1 to $\beta_2 = 1.22$ for the non-linear model M2; whilst the t-statistics associated with the book value coefficient increase significantly from 6.55 for M1 to 12.60 for M2. In contrast, the valuation coefficient associated with the earnings variable grows from $\beta_1 = 4.09$ for M1 to $\beta_1 = 6.51$ for M2 with the corresponding t-statistics increasing from 3.83 to 10.42. Moreover, all the coefficients associated with the non-linear terms in M2 are significantly different from zero at conventional levels. The significance of the coefficients associated with the non-linear terms in M2 are consistent with the real option valuation hypothesis and indicates that the relationship between the market value of a firm's equity and its accounting variables is non-linear. Here it also needs to be emphasised that the inclusion of non-linear terms as components of the equity valuation model results in a significant improvement in the explanatory power of the empirical analysis with the adjusted R^2 value rising from 22.53% for the pure linear model, M1, to 38.15% for the non-linear model, M2. The substantial increase in the R^2 value indicates that the non-linear equity valuation model provides a more complete description of the relationship between the market value of equity and its determining variables than the traditional linear equity valuation model. Finally, Table 5.2 summarises the F-statistics for the M1 and M2 regression models based on the hypothesis that the R^2 value is insignificantly different from zero. Note that all F-statistics are statistically significant at any reasonable level thereby confirming that one can reject the maintained hypothesis that $R^2 = 0$ for both regression models.

Table 5.2 also summarises the Durbin-Watson first order autocorrelation statistics for serial correlation in the residuals. For the Durbin-Watson statistics our sample of $N = 9,209$ firm-year observations are ordered from the lowest to highest in terms of the profitability ratio, $q(t)$, which is the earnings to book value ratio (as

previously defined in section 4.3.1 of Chapter 4). The residuals from the ordered sequence based on the $q(t)$ ratios are then calculated for both regression models and the Durbin-Watson statistics are computed for each model separately. The Durbin-Watson statistics are all slightly below their expected value of two, thereby indicating that the residuals in the regression models vary systematically according to the level of firm profitability. Fortunately, this is an issue that can be addressed by dividing firms into one of three levels of operational efficiency. Before doing so, however, the test results for the presence of multi-collinearity in the independent variables for the M2 regression model are summarised. As with earlier analysis, we implement the condition number test to detect potential problems of multi-collinearity with the M2 model. The results of the condition number test, as reported in Table 5.3, shows that the highest condition index is 13.155 which is within the generally accepted value of 15 at which multi-collinearity in the determining variables may become an issue (Belsley et al., 1980).

Table 5.3
Multi-collinearity Diagnostics for M2 Regression Model (Full-sample)

Model Dimension	Eigenvalue	Condition Index	Variance Proportions						
			(Constant)	$x(t)$	$b(t)$	$b(t)^2$	$x(t)^2$	$b(t)^3$	$x(t)^3$
1	3.024	1	0	0.02	0.02	0.01	0	0.01	0
2	1.875	1.27	0	0.04	0.06	0.02	0	0.02	0
3	1.002	1.737	0.96	0	0.01	0	0	0	0
4	0.641	2.172	0.01	0.14	0.44	0.04	0	0.02	0
5	0.349	2.942	0.01	0.73	0.38	0.04	0.01	0	0.01
6	0.09	5.786	0.02	0.06	0.09	0.87	0	0.93	0
7	0.017	13.155	0.01	0.01	0.01	0.02	0.98	0.01	0.98

5.3.2 Descriptive Statistics and Empirical Results on Efficiency Groups

As previously noted in section 2.6 of Chapter 2 and section 3.4 of Chapter 3, the valuation coefficients associated with the accounting (that is, the determining) variables will change according to the level of the firm's operational efficiency. In particular, when a firm's financial situation is deteriorating so that it may be required to modify or even abandon its existing investment opportunity set, then the firm's adaptation option value will become an increasingly significant component of the overall market value of the firm's equity. In this scenario, market participants will focus on the book value of the firm's equity in assessing the value of the equity security. In contrast, when a firm's current operations are highly profitable, market participants will focus on earnings in their valuation procedures so that the market value of equity will increasingly reflect the value of the growth options available to the firm. In our empirical tests, it is expected that for firms with low efficiency (high efficiency) where abandonment option (growth option) value is significant, the relationship between the market value of equity and the accounting variables, that is, earnings and book value, will be non-linear. However, for firms with moderate efficiency where neither the abandonment option nor the growth option to expand the firm's productive activities will make a significant contribution to the overall market value of the firm's equity, it is expected that the relationship between the market value of a firm's equity and its accounting variables to be approximately linear. Given this, the sample of $N = 9,209$ firm-years of data is divided into three efficiency groups where efficiency is measured by the earnings to book value ratio, $q(t)$, as in Chapter 4. All firm-year data with negative earnings are included in the low-efficiency group, since otherwise firm-years with a negative book value and negative earnings will return a positive $q(t)$ ratio and would therefore be included in either the steady-state or high-efficiency groups. In the efficiency sub-sample empirical tests, all firm-year data are assigned to three equally numerous groups. The bottom tertile comprises of the $N_1 = 3,069$ firm-years with the lowest operational efficiency; the middle tertile is comprised of the $N_2 = 3,070$ firm-years with steady-state or

moderate operational efficiency; while the top tertile is comprised of the $N_3 = 3,070$ firm-years with the highest level of operating efficiency.

A summary of the distributional properties of the explanatory variables across the three levels of operational efficiency is contained in Table 5.4. The first panel of Table 5.4 shows that the mean and median of the centred book value of equity across the $N_1 = 3,069$ firm-years comprising the sample of low-efficiency observations are zero and -0.15, respectively. Likewise, the standard deviation of the centred book values across the sample of low-efficiency observations is 2.33. Finally, the minimum centred book value of the sample of low-efficiency observations is -26.06 whilst the maximum centred book value is 42.30. The remaining statistics in Table 5.4 are to be similarly interpreted.

This low-efficiency group comprises firms with negative earnings and negative book value, firms with either negative earnings or negative book value and firms with both positive earnings and positive book value but with a low earnings to book value ratio, $q(t)$. Here it will be recalled that prior empirical studies (as in section 2.6 of Chapter 2 and section 3.4 of Chapter 3) show that book value is a more important determinant than earnings in the equity valuation process for firms with low operational efficiency. These findings are consistent with the real option hypothesis that for firms with low operational efficiency, abandonment option value is the predominant component of the market value of equity; and thus, the proxy for abandonment option value - namely, the book value of equity - is a more important determinant than earnings in the equity valuation process. However, in contrast to previous findings and the real option hypothesis, the empirical results as summarised in Table 4.5 of Chapter 4, show that book value performs no better than earnings as an explanatory variable for the equity prices of low-efficiency firms. This suggests that for low-efficiency firms the purely linear equity valuation models summarised in Table 4.5 return a biased and inconsistent representation of the relationship between the market value of equity and its determining variables. However, with the inclusion of the non-linear terms which approximate for real option value, it would be expected that the book value of equity plays a more prominent role than earnings in the empirical relationship between the market value

of equity and its determining variables. Moreover, one would expect the estimated coefficients associated with the non-linear terms to return compelling t-statistics.

Table 5.4
Distributional Properties of Low-efficiency, Steady-state and High-efficiency Sub-samples

	$x(t)$	$b(t)$	$b^2(t)$	$b(t)x(t)$	$x^2(t)$	$b^3(t)$	$b^2(t)x(t)$	$b(t)x^2(t)$	$x^3(t)$
Low-efficiency (Firm-Year $N_1 = 3,069$)									
Mean	0.00	0.00	5.42	-0.45	0.67	83.56	-14.56	8.64	-11.21
Median	0.15	-0.15	0.56	0.00	0.03	0.00	0.03	0.00	0.00
Std. Deviation	0.82	2.33	63.47	17.33	16.69	2439.48	570.68	454.37	436.63
Minimum	-27.96	-26.06	0.00	-896.47	0.00	-17693.91	-28739.10	-421.56	-21867.64
Maximum	5.38	42.30	1789.04	66.23	781.99	75670.81	599.06	25069.03	155.63
Steady-state (Firm-Year $N_2 = 3,070$)									
Mean	0.00	0.00	1.60	0.12	0.01	3.52	0.26	0.02	0.00
Median	-0.02	-0.23	0.59	0.04	0.00	-0.01	0.00	0.00	0.00
Std. Deviation	0.11	1.26	4.51	0.35	0.03	32.66	2.33	0.21	0.02
Minimum	-0.15	-2.11	0.00	-0.03	0.00	-9.45	-0.69	-0.05	0.00
Maximum	0.81	10.14	102.83	6.90	0.66	1042.80	61.80	5.32	0.53
High-efficiency (Firm-Year $N_3 = 3,070$)									
Mean	0.00	0.00	2.71	0.50	0.17	20.22	3.53	0.89	0.36
Median	-0.11	-0.35	0.77	0.13	0.04	-0.04	-0.01	0.00	0.00
Std. Deviation	0.41	1.65	21.60	3.71	1.36	671.87	88.93	21.35	9.66
Minimum	-0.41	-1.99	0.00	-2.75	0.00	-7.93	-1.61	-6.16	-0.07
Maximum	8.03	33.28	1107.55	132.92	64.54	36859.35	4423.48	1015.08	518.54

Variable Definitions: $b(t)$ = Book value of equity per share at the beginning of year t . It represents the book value (proportioned common equity divided by outstanding shares) at the company's fiscal year end, $(t - 1)$ (Datastream mnemonic WC05476). $x(t)$ = Earnings per share for year t . It represents the earnings for the 12 months ended the fiscal year t . Earnings per share is profit after tax, minority interest and preferred dividends but before extraordinary items (Datastream mnemonic WC05201). All descriptive statistics variables are based on centred data.

Table 5.5
Industrial Distribution for Low-efficiency, Steady-state and High-efficiency
Sub-samples

Industrial Distribution				
Industry	Low-efficiency Firm-Year N₁ = 3,069	Steady-state Efficiency Firm-Year N₂ = 3,070	High-efficiency Firm-Year N₃ = 3,070	Total
Basic Materials ¹⁹	554	505	556	1,615
Consumer Goods ²⁰	637	503	473	1,613
Consumer Services ²¹	278	322	288	888
Financials ²²	348	287	390	1,025
Health Care ²³	207	226	257	690
Industrials ²⁴	726	826	766	2,318
Oil & Gas ²⁵	19	13	42	74
Technology ²⁶	157	171	131	459
Telecommunication ²⁷	12	8	3	23
Utilities ²⁸	131	209	164	504
Total	3,069	3,070	3,070	9,209

Industry definitions are from Datastream.

¹⁹ Basic Materials industry includes sectors of chemicals, forestry & paper, industrial metals & mining and mining.

²⁰ Consumer Goods industry includes sectors of automobiles & parts, beverages, food producers, household goods & home construction, leisure goods, personal goods and tobacco.

²¹ Consumer Services industry includes sectors of food & drug retailers, general retailers, media and travel & leisure.

²² Financials industry includes sectors of banks, nonlife insurance, life insurance, real estate investment & services, real estate investment trusts, financial services, equity investment instruments and non-equity investment instruments.

²³ Health Care industry includes sectors of health care equipment & services and pharmaceuticals & biotechnology.

²⁴ Industrials industry includes sectors of construction & materials, aerospace & defense, general industrials, electronic & electrical equipment, industrial engineering, industrial transportation and support services.

²⁵ Oil & Gas industry includes sectors of oil & gas producers, oil equipment, services & distribution and alternative energy.

²⁶ Technology industry includes sectors of software & computer services and technology hardware & equipment.

²⁷ Telecommunications industry includes fixed line telecommunications and mobile telecommunications.

²⁸ Utilities industry includes sectors of electricity and gas, water & utilities.

The group with relatively higher and positive operational efficiency, $q(t)$, is classified as being comprised of steady-state firms. The second panel of Table 5.4 summarises the distributional properties of the independent variables for the $N_1 = 3,070$ firm-year steady-state observations. Steady-state efficiency firms operate sufficiently well enough to neglect the abandonment options available to them but lack the potential to expand their productive activities. This means that for steady-state firms, neither the abandonment option nor the growth option to expand the firm's existing operations will make a significant contribution to the overall market value of the firm's equity. This means that for steady-state firms it would be expected that our empirical results will be consistent with the predictions of the Ohlson (1995) model that the market value of the firm's equity will be an approximately linear function of the book value of equity and earnings. This in turn will mean that the coefficients associated with the non-linear terms incorporated into the equity valuation model are unlikely to show statistical significance.

The group with the highest operational efficiency, $q(t)$, is classified as high-efficiency firms. The third panel of Table 5.4 summarises the distributional properties of the independent variables for the $N_1 = 3,070$ firm-years comprising our sample of high-efficiency observations. Firms which fall into this category have relatively large earnings, a high earnings to book value ratio, $q(t)$, and the highest level of operational efficiency. Consistent with previous studies, earnings would be expected to be the predominant determinant of the market value of equity for firms comprising this efficiency classification. Moreover, firms with high operational efficiency are more likely to change their current investment opportunity sets and to expand their current productive activities. Thus, for firms in this efficiency classification the growth option value will contribute significantly to the market value of equity and lead to a highly non-linear relationship between the market value of equity and its determining variables. Therefore the coefficients associated with the non-linear terms, which are the proxies of real option value, are expected to be statistically significant for the high-efficiency firms.

Finally, in Table 5.5 the industry classifications by efficiency level are summarised for each of the firm-years comprising this sample.

I would also emphasise that the multi-collinearity issues identified in earlier sections of this chapter will mean that the following reduced form interpretations of the benchmark non-linear pricing model are applied to each of the three efficiency classifications:

Low-efficiency firms:

$$P(t) = \beta_0 + \beta_1 x(t) + \beta_2 b(t) + \beta_3 b^2(t) + \beta_4 b(t)x(t) + \beta_5 x^2(t) + \beta_6 b^3(t) + \beta_8 b(t)x^2(t) + e_3(t) \quad (5.10)$$

Steady-state firms:

$$P(t) = \beta_0 + \beta_1 x(t) + \beta_2 b(t) + \beta_3 b^2(t) + \beta_5 x^2(t) + \beta_7 b^2(t)x(t) + e_4(t) \quad (5.11)$$

High-efficiency firms:

$$P(t) = \beta_0 + \beta_1 x(t) + \beta_2 b(t) + \beta_4 b(t)x(t) + \beta_7 b^2(t)x(t) + \beta_9 x^3(t) + e_5(t) \quad (5.12)$$

I also conduct simple linear regressions for each efficiency group based on model (5.8) which only includes earnings and book value in linear form as determining variables.

Table 5.6 provides a summary of the regression results for the three efficiency subsamples. White's (1980) heteroskedastic-consistent covariance matrix estimation procedure is used in all regressions to correct the estimates for any unknown forms of heteroskedasticity. Student t-statistics are listed below all estimates of the regression coefficients. The first panel of this table summarises the empirical results generated by regression model (5.10) for the low-efficiency subsample. It

shows that the valuation coefficient associated with earnings for the purely linear (M1) regression model is $\beta_1 = 0.48$ with a corresponding t-statistics of 4.02. Moreover, the coefficient associated with book value is $\beta_2 = 0.29$ with a corresponding t-statistics of 3.82. Note how for low-efficiency firms book value shows less importance than earnings in the linear equity valuation model, something that is consistent with the empirical results summarised in Chapter 4. However, when non-linear and cross-product terms are included in this regression model - namely $b^2(t)$, $b(t)x(t)$, $x^2(t)$, $b^3(t)$, and $b(x)x^2(t)$ - the coefficient associated with book value is $\beta_2 = 0.63$ with a compelling t-statistic of 7.14, whilst the coefficient associated with earnings is $\beta_1 = 0.69$ with a much less compelling t-statistics of 3.78. Of more importance, however, is that the coefficients associated with the non-linear terms, $b^2(t)$, $x^2(t)$, and $b^3(t)$, are all significant at the 5% level and the coefficient associated with $b(t)x^2(t)$ is significant at the 10% level. It will also be noted that the inclusion of the non-linear terms increases the explanatory power of the equity valuation model by about three percentage points from $R^2 = 2.36\%$ to $R^2 = 5.30\%$. These results are compatible with our expectation that adaptation value will make a significant contribution to the overall market value of equity for low-efficiency firms. Despite this, however, the explanatory power of both the linear and non-linear models for low-efficiency firms are low with the adjusted R^2 value ranging from $R^2 = 2.36\%$ to $R^2 = 6.67\%$ (as shown in Table 5.6 as well as Table 4.5 and Table 4.13 in section 4.3 of Chapter 4). In section 5.4, some possible explanations are provided for the low explanatory power of both the linear and non-linear equity valuation models as they apply to the data comprising the sub-sample of low-efficiency firms.

The empirical results for the steady-state sub-sample of firms are summarised in the second panel of Table 5.6. Note that the coefficients and t-statistics associated with earnings and book value are comparatively stable as we move from the linear to the non-linear valuation model. Moreover, the coefficients associated with earnings substantially exceed those associated with book value. These results are compatible with the empirical results summarised in the second panel of Table 4.5

where the coefficients associated with the earnings variable are roughly nine times the coefficients associated with book value. Moreover, Table 5.6 shows that the coefficients associated with all non-linear terms, $b^2(t)$, $x^2(t)$, and $b^2(t)x(t)$, do not show statistical significance at any of the conventional levels. For example, the coefficient associated with $b^2(t)$ is $\beta_3 = -0.07$ with a corresponding t-statistic of -0.70. Furthermore, that the adjusted R^2 value of 25.07% for the steady state efficiency non-linear equity valuation model represents only a very marginal improvement over the $R^2 = 25.02\%$ value obtained for the pure linear [or Ohlson (1995)] equity valuation model for steady state firms. Thus for the firms comprising the steady-state efficiency classification, incorporating non-linear terms into the equity valuation process does not appear to bring any particular advantage over the more parsimonious linear model with only earnings and book value as explanatory variables. In other words, the market value of equity for firms comprising the steady-state efficiency classification would appear to have an approximate linear relationship with earnings and the book value of equity. It will also be observed that the coefficients associated with the earnings variables increase as one moves from the low-efficiency classification of firms into the steady-state efficiency classification of firms. This shows that investors view reported earnings as containing more information relevant to the value of a firm's equity in comparison to book value for firms with steady-state efficiency. In other words, earnings becomes increasingly more important in determining the market value of a firm's equity as the firm's operational efficiency increases. This in turn will mean the market value of equity for firms falling in the steady-state efficiency classification are more sensitive to changes in earnings than to changes in book value.

The focus of our attention now turns to the high-efficiency sub-sample of firms. The results summarised in the third panel of Table 5.6 show that it is highly unlikely that a purely linear equity valuation model could adequately capture the relationship between equity value and its accounting (that is, determining) variables for firms in the high-efficiency classification. In particular, the coefficients associated with the non-linear terms, $b^2(t)x(t)$ and $x^3(t)$, are statistically significant

at the 5% level whilst the coefficient associated with $b(t)x(t)$ is statistically significant at the 10% level. Consistent with the empirical results summarised in section 2.6 of Chapter 2, such results show that earnings has a more compelling role to play in the equity valuation process than the book value of equity in both the linear and non-linear models. Moreover, the earnings variable shows a more compelling relationship with the market value of equity in the non-linear equity valuation model (M2) with a t-statistic of 9.61 than its counterpart in the linear equity valuation model (M1), which returns a lesser t-statistics of 7.08. Of even more significance, however, is the fact that the explanatory power of the non-linear approximation model is $R^2 = 55.14\%$ in comparison with the explanatory power of $R^2 = 49.63\%$ for the linear model. These results are compatible with the expectation that growth option value will make a significant contribution to the overall market value of equity for high-efficiency firms.

Table 5.6 also presents the Durbin-Watson statistics associated with each regression model. The calculation of the Durbin-Watson statistics follows the previous procedure of ranking the firm-years in terms of the profitability ratio, $q(t)$. The residuals from the ordered sequence based on the $q(t)$ ratios were then calculated for all three regression models and the Durbin-Watson statistic computed for each model separately. For all three regression models the Durbin-Watson statistics cluster around their expected value of two, thereby confirming that there are no significant problems with autocorrelated residuals in our regression models. Thus, classifying firms into one of three groups based on their operational efficiency addresses the issue of serial correlation that emerged with the regression procedures based on the pooled data. Moreover, all F-statistics are statistically significant at any reasonable level thereby confirming that the maintained hypothesis that $R^2 = 0$ can be rejected for all three regression models.

As a final exercise the condition number tests are used in order to assess whether our regression procedures might be afflicted by problems of multi-collinearity. The results of the condition number test, as reported in Tables 5.7 through Table 5.9, show that the largest condition index across the three tables amounts to 12.32

which is well within the generally accepted value of 15 at which multi-collinearity in the independent variables may become an issue.

Table 5.6

Coefficients Estimate for Linear Model (M1) and Reduced High Order Approximation Model (M2) for Low-efficiency, Steady-state and High-efficiency Sub-samples

$$\mathbf{M1:} P(t) = \beta_0 + \beta_1 x(t) + \beta_2 b(t) + e_1(t)$$

$$\mathbf{Original\ High\ Order\ Approximation\ Model - M2:} P(t) = \beta_0 + \beta_1 x(t) + \beta_2 b(t) + \beta_3 b^2(t) + \beta_4 b(t)x(t) + \beta_5 x^2(t) + \beta_6 b^3(t) + \beta_7 b^2(t)x(t) + \beta_8 b(t)x^2(t) + \beta_9 x^3(t) + e_2(t)$$

Valuation Model	Model Coefficients t-statistics Listed Below Coefficient										Model Adjusted R ²	Model F-statistic & DW Value
	β_0	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9		
Low-efficiency (Firm-Year N ₁ = 3,069) Linear Model (M1)	6.66 84.08	0.48 4.02	0.29 3.82								2.36%	F=38.091 DW=1.956
	6.62 84.84	0.69 3.78	0.63 7.14	0.02 2.74	-0.02 -0.91	0.03 2.84	-0.00 -4.23	- -	-0.00 -1.71	- -	5.30%	F=25.537 DW=1.948
Steady-state (Firm-Year N ₂ = 3,070) Linear Model (M1)	7.51 100.90	10.74 4.52	1.05 5.23								25.02%	F=512.966 DW=1.987
	7.61 64.45	10.18 4.29	1.11 6.10	-0.07 -0.70	- -	-3.15 -0.26	- -	0.19 1.32	- -	- -	25.07%	F=206.369 DW=1.989

High-efficiency (Firm-Year N ₃ = 3,070)												
Linear Model (M1)	10.64 84.33	17.28 7.08	-0.08 -0.17								49.63%	F=1,513.07 DW=1.964
Reduced High Order Approximation (M2)	10.24 49.29	12.37 9.61	0.45 1.65	- -	0.99 1.80	- -	- -	-0.05 -3.17	- -	0.16 2.15	55.14%	F=755.45 DW=1.969

White (1980) adjusted t-statistics are listed below the coefficients.

Variable Definitions: $b(t)$ = Book value of equity per share at the beginning of year t . It represents the book value (proportioned common equity divided by outstanding shares) at the company's fiscal year end, $(t - 1)$ (Datastream mnemonic WC05476). $x(t)$ = Earnings per share for year t . It represents the earnings for the 12 months ended the fiscal year t . Earnings per share is profit after tax, minority interest and preferred dividends but before extraordinary items (Datastream mnemonic WC05201).

Table 5.7
Multi-collinearity Diagnostics (Low-efficiency Sub-sample)

Model Dimension	Eigenvalue	Condition Index	Variance Proportions							
			(Constant)	x(t)	b(t)	b ² (t)	b(t)x(t)	x ² (t)	b ³ (t)	b(t)x ² (t)
1	4.062	1	0	0.01	0.01	0	0	0.01	0	0
2	1.767	1.516	0	0.01	0.05	0.02	0	0.01	0.02	0
3	1.003	2.012	0.96	0	0	0	0	0	0	0
4	0.503	2.842	0	0.32	0.06	0	0.02	0.01	0	0.02
5	0.456	2.985	0.02	0.03	0.58	0.1	0	0	0.01	0
6	0.107	6.148	0.01	0.62	0.01	0.02	0.04	0.91	0	0.01
7	0.075	7.359	0.01	0.01	0.25	0.84	0.01	0.03	0.81	0.01
8	0.027	12.318	0	0	0.05	0.01	0.92	0.03	0.16	0.95

Table 5.8
Multi-collinearity Diagnostics (Steady-state Sub-sample)

Model Dimension	Eigenvalue	Condition Index	Variance Proportions					
			(Constant)	b(t)	x(t)	b ² (t)	x ² (t)	b ² (t)x(t)
1	3.749	1	0	0.01	0.01	0.01	0.01	0.01
2	1.187	1.777	0.30	0.02	0.02	0.01	0	0
3	0.676	2.354	0.30	0.04	0.03	0.01	0.01	0.04
4	0.257	3.822	0	0.09	0.07	0.16	0.24	0
5	0.074	7.135	0.40	0	0	0.51	0.27	0.95
6	0.057	8.123	0	0.84	0.87	0.31	0.47	0

Table 5.9
Multi-collinearity Diagnostics (High-efficiency Sub-sample)

Model Dimension	Eigenvalue	Condition Index	Variance Proportions					
			(Constant)	b(t)	x(t)	x ³ (t)	b(t)x(t)	b ² (t)x(t)
1	3.306	1	0	0.02	0.02	0.01	0	0.01
2	1.040	0.783	0.59	0.03	0.03	0.01	0	0
3	0.894	1.924	0.24	0.10	0.06	0.05	0	0.01
4	0.550	2.451	0	0.03	0.08	0.21	0	0.07
5	0.176	4.339	0	0.76	0.75	0.18	0	0.04
6	0.034	9.889	0.16	0.06	0.06	0.54	0.99	0.87

5.4 Low Explanatory Power for the Low-efficiency Group of Firms

The empirical results summarised in section 4.3 of Chapter 4 and in section 5.3 of Chapter 5 raise two crucial concerns. First, Ohlson (1999) suggests that the earnings of low-efficiency firms will contain only limited information in regard to equity values since investors will view the low or negative earnings associated with such firms as being of a transitory nature and therefore, largely irrelevant to the equity valuation process. Given this, it is unfortunate that the empirical results in this study show that the earnings of low-efficiency firms listed on the SSE have a significant positive association with the market value of equity. The valuation coefficient associated with earnings in the non-linear valuation model amounts to $\beta_1 = 0.69$ with a highly significant t-statistic of 3.78. Moreover, the earnings valuation coefficient in the non-linear model slightly exceeds the valuation coefficient, $\beta_2 = 0.63$ associated with the book value of equity, although the t-statistic associated with this latter valuation coefficient is a far more compelling 7.14. Second, as suggested in Hayn (1995) and Burgstahler and Dichev (1997) under the abandonment option hypothesis one would expect that for low-efficiency firms, book value would provide a good approximation for the adaptation value of equity since at liquidation - when the recursion value of equity is very low - book value is largely independent of a firm's current operations (or current earnings) and is similar to the liquidation value of the firm. Given this, one would expect book value to be the predominant determinant of the market value of equity for firms comprising the low-efficiency classification. However, as will be noted from the first panel of Table 5.6 and inconsistent with the abandonment option hypothesis, book value along with other explanatory variables can only explain about 5% of the variation in the market value of equity for low-efficiency firms listed on the SSE. This result is in sharp contrast to what is generated by the equivalent U.S. data, where book value and earnings alone account for 42% of the variation in the market value of equity for financially distressed firms (Collins et al., 1999).

It can be noted here that these results are consistent with prior empirical studies on the Chinese stock markets. Based on sample data of listed firms in China from

1993 to 2002, Xu and Li (2005) observe that the explanatory power of earnings and book value to the market value of equity for loss-making firms is less than 1%. They conclude that when Chinese investors price loss-making firms, they are more inclined to put more weight on non-accounting information rather than traditional accounting information (e.g. book value and earnings). Xu and Li (2005) show that firm size (as measured by the book value of assets) is highly correlated with the efficiency classification level attained by the firm. In particular, relatively large firms tend to occupy the high-efficiency classification whilst relatively small firms tend to occupy the low-efficiency classification. Moreover, Xu and Li (2005) also show that the explanatory power of traditional accounting information to the market value of equity declines as one moves from the high-efficiency classification to the low-efficiency classification (Xu & Li, 2005). The empirical results in this study are consistent with the results reported by Xu and Li (2005): firm-years falling into the low-efficiency classification generate the lowest explanatory power of about $R^2 = 5\%$. Moreover, the low-efficiency classification is comprised of firms with an average total asset value of 4,356,876,044 Chinese Yuan (CNY) (equivalent to 697,100,167.04 USD). This contrasts with firm-years falling into the steady-state efficiency category which generate a moderate explanatory power of about $R^2 = 25\%$ and which is comprised of firms with an average total asset value of 6,291,447,050 CNY (equivalent to 1,006,631,528 USD). Firm-years in the high-efficiency category which generate the highest explanatory power of about $R^2 = 55\%$ are of the largest size with an average total asset value of 104,082,381,400 CNY (equivalent to 16,653,181,024 USD).

There are several possible explanations as to why the market value of equity bears such a poor relationship with earnings and the book value of equity for the low-efficiency firms comprising the sample in this study. First amongst these is that when a firm finds itself in financial difficulties it will often liquidate its assets quickly and at depressed prices in order to shore up its financial position. In such circumstances it is unlikely that book value will provide a faithful representation of the adaptation value of the firm's equity (Damodaran, 2009).

Second, investors also price low-efficiency firms in accordance with the probability that the firm will be able to address the financial difficulties it faces and thereby eventually move into either the steady-state or the high-efficiency classifications (Davidson & Tippett 2012, pp. 225-227). A good example is provided by firms with large R&D outlays and low profits (and thus, low efficiency as we have defined it). Such firms are unlikely to exercise their abandonment options. On the contrary, large R&D expenditure is often viewed as signalling the potential for large future returns (Joos & Plesko, 2005). For firms in this scenario, book value is not an appropriate explanatory variable for the market value of equity. In particular, for firms with negative book value, R&D expenditure, rather than book value, plays a far more important role in the equity valuation process (Jan & Ou, 2011; Jiang & Stark, 2013). It can be noted here that based on 648 firm-years of data from the SSE covering the period from 2001 to 2006, R&D expenditure shows a highly significant correlation with the market value of corporate equity (Xiao-Hong & Yu-Hong, 2008). Given this, without the inclusion of R&D information the equity valuation models applied in both this chapter as well as in Chapter 4 do not provide a satisfactory explanation to the market value of equity for the low-efficiency firms listed on the SSE.

The third possible explanation for the low R^2 values obtained for low-efficiency firms is that the market value of low-efficiency firms may be largely determined by the likelihood of “shell selling” (that is, reverse mergers) rather than through the information recorded in their financial statements. There is a strong demand for public company “shells” since private companies can save substantial time and cost in going public by acquiring a “shell” in comparison to having to go through an IPO (Yan et al., 2009). Given this, the shareholders of a given low-efficiency “shell company” would expect to benefit from “shell selling” and thereby will put a much higher value on the firm than that indicated by the book values summarised in its financial statements. This in turn will mean that equity valuation models based on traditional accounting information cannot fully explain the market value of equity for low-efficiency firms.

The fourth potential reason for the low R^2 values associated with low-efficiency firms is that the equity valuation models applied to our data do not capture information relating to the likelihood of “restructuring” which may have a significant impact on the market value of equity for low-efficiency firms. When adverse financial circumstances force the firm into making fundamental changes to its current investment opportunity set, negative (low) earnings or book value loses relevance to the market value of equity but signals the likelihood of corporate restructuring. Such restructuring effectively entails significant changes to management, operations, ownership structure and assets etc., all of which are expected to boost future profits. This hypothesis is consistent with the commonly observed phenomenon that after a firm’s loss-making announcement, the market value of the firm’s equity surges (Yang & Bo, 2010). Unfortunately, it is difficult to incorporate information relating to the likelihood of restructuring into the standard equity valuation models.

Fifth, the SSE is an emerging capital market under heavy intermediation on the part of government. Given this, investors are less concerned with a firm’s deteriorating financial status and focus more on the firm’s political affiliations when making investment decisions. For example, it is unlikely that firms which are either controlled by or supported by the government will go into bankruptcy, since they normally have relatively easy and unrestricted access to capital, such as bank loans on favourable terms due to government support. In particular, in China, the banking system is under the control of government and provides important support to firms which have either political connections with government or direct government involvement. Moreover, investors would expect the government to increase the market price of firms associated with government through the provision of finance on favourable terms, enacting preferential tax policy, rescheduling debt payments or even pardoning outstanding and burdensome debt, etc. (Yan et al., 2009). Hence, given the level of government control and outright intervention in Chinese capital markets, SSE investors are more inclined towards policy-oriented speculation rather than making investment decisions based on information appearing on firms’ financial reports (Wang et al., 2006).

Sixth, when a loss-making firm is a subsidiary of a group company, investors will not care too much about the subsidiary's financial situation. Investors will expect group head office to raise the capital required to bail out the subsidiary thereby alleviating its financial difficulties and even creating growth opportunities for it. In this case, investors would be more sensitive to managerial behaviour and ingenuity rather than the accounting information recorded in the subsidiary firm's financial statements. For instance, "a plausible indicator of firms' future earnings can be insider transactions on their personal stock holdings since it likely reflects their expectations about the firm's future performance Insider buying of company stock is viewed as a reflection of managerial optimism ... given the insider's proximity to the business operations" (Aier, 2013, p. 10). In particular, insiders are more aware of the government's future policies, future material costs, (especially when material costs are imposed by the government), access to capital, possible R&D support from the government, etc. (Aier, 2013). Given this, the market value of a firm's equity would largely reflect investors' responses to managerial behaviour and ingenuity. However, this response is not captured by the models applied in both this chapter as well as Chapter 4.

In summary and consistent with prior research, our results as summarised in Table 5.6 show that book value has a significant positive association with the market value of equity for low-efficiency firms listed on the SSE. However, the explanatory power of book value, earnings and other high order terms to the market value of equity for low-efficiency firms listed on the SSE is substantially lower than that of US loss-making firms (Collins et al., 1999). Moreover, the explanatory power of book value, earnings and other high order terms to the market value of equity for low-efficiency firms listed on the SSE is also substantially lower than the explanatory power of their counterparts in the steady-state and the high-efficiency classifications of firms listed on the SSE. These results indicate that investors value loss-making or low-efficiency firms listed on the SSE differently from the loss-making firms in US capital markets and also differently from the more profitable firms listed on the SSE. Moreover, the low explanatory power of these models for the low efficiency firms listed on the SSE also suggests that book value

is neither a dominating explanatory variable to the market value of equity nor a proper proxy for the abandonment option value for low-efficiency firms.

In this section, six possible reasons have been discussed that could lead to the low explanatory power of our equity valuation models for low-efficiency firms listed on the SSE. The conclusion is that the market value of equity for low-efficiency firms listed on the SSE is mainly determined by information other than book value and earnings. Hence, equity valuation models which encapsulate only traditional accounting information as explanatory variables cannot provide a satisfactory explanation as to how the market value of equity is determined for low-efficiency firms listed on the SSE.

5.5 Principal Component Analysis

Section 5.3 addresses the multi-collinearity problem by omitting highly correlated polynomial terms from the benchmark model employed in our empirical work. Unfortunately, omitting variables in this way raises two crucial concerns. First, the original high order approximation model is obtained by applying a Laguerre polynomial expansion to the benchmark model of Davidson and Tippett (2012) which forms the basis for all of the empirical work conducted to this point in the chapter. However, omitting variables which are inherent to the equity valuation process will more than likely hinder our understanding of the way equity prices are determined in practice. Second, omitting potentially important variables opens up the criticism that our empirical analysis might suffer from omitted variables bias. It then follows that all the coefficients estimated in my empirical analysis will be biased and inconsistent (Ofir & Khuri, 1986). It is because of this that a Principal Component Analysis (PCA) is now applied to the data on which our empirical analysis has so far been based. It is well known that this will remedy the multi-collinearity problem without sacrificing any of the information contained in the original data on which the benchmark model is based. There is, however, a downside to the application of PCA - and this is that it can often be difficult to interpret what the principal components actually represent.

5.5.1 PCA on Pooled Data

In this section PCA is applied to the same pooled data on which the empirical analysis in section 5.3.1 is based. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy for the pooled sample is 0.772 which indicates that PCA can be legitimately applied to the pooled sample dataset.²⁹ The following results are generated by PCA using the Varimax (that is, orthogonal) rotation option.³⁰

Column 3 of Table 5.10 shows the percentage of the variance in the original variables that is accounted for by each of the principal components. For example, the first and second principal components explain 59.755% and 23.132% of the total variance in the independent variables, respectively. As shown in column 4 of Table 5.9, together these two principal components retain 82.886% of the total variance in the original independent variables. Table 5.11 summarises the factor loadings associated with each of the original independent variables for each of the nine principal components obtained in this analysis. Note how the first principal component loads 0.670 onto the earnings variable, $x(t)$, 0.934 onto the interaction term, $x(t)b(t)$, between earnings and book value, 0.939 onto the interaction term, $b^2x(t)$, between squared book value and earnings and 0.918 onto the cubed value of earnings, $x^3(t)$. Thus, this first principal component may be broadly interpreted as an “earnings” principal component. Similarly, the second principal component loads heavily onto the book value elements of the vector and may therefore be interpreted as a “book value” principal component. Moreover, the third principal component loads broadly onto both the earnings and book value elements of the vector and may therefore be interpreted as “joint earnings-book

²⁹ The Bartlett Test of Sphericity statistic amounts to 134,725.23 with 36 degrees of freedom. A test statistic of this magnitude indicates that it is unlikely the sample correlation matrix is compatible with the identity matrix at any of the conventional levels of significance.

³⁰ In sections 5.5.1 to 5.5.4, the market value of equity for the pooled sample of firms and three efficiency sub-samples are regressed on the nine principal components obtained for each data set. In so doing all the information embedded in our original data are retained. This in turn means that the explanatory power of the principal components regressions will be the same as the regressions conducted on the original data. However, in contrast to the original regressions, the PCA based regressions completely address the issue of co-linear determining variables.

value” principal component. Finally, note that the factor loadings for all other principal components do not exceed 0.40 in absolute value.

The results obtained from regressing the market price of equity against the nine principal components obtained for the pooled data are summarised in the first panel of Table 5.12. The coefficients associated with all components, except components 2 and 7, are statistically significant. The adjusted R^2 shows that the nine principal components obtained for the pooled data explain 41.54% of the variability in the market value of equity for the SSE firm-year data on which our empirical analysis is based.³¹ Recall here that based on the same pooled sample dataset, the adjusted R^2 value generated by the pure linear equity valuation model with only earnings and book value as explanatory variables amounts to 22.53% (as summarised in Table 5.2 in section 5.3.1). The substantial increase in the adjusted R^2 value shows that the non-linear terms, which proxy for a firm’s real option value, play an important role in determining market value of equity for firms listed on the SSE. Thus it necessarily follows that there is an evident non-linear relationship between the market value of equity and the accounting (that is, determining) variables employed in our empirical analysis. Also, the adjusted R^2 value generated by the nine principal components is consistent with the adjusted R^2 value of 38.15% generated by the reduced form non-linear regression model (as summarised in Table 5.2 in section 5.3.1) which also shows that the non-linear terms make a significant contribution towards explaining the contemporaneous market value of equity.

Table 5.12 also summarises the Durbin-Watson first order autocorrelation statistics for serial correlation in the residuals. The Durbin-Watson statistic is calculated in the same way as in previous sections. The Durbin-Watson statistic is slightly below the expected value of two, thereby indicating that the residuals in the

³¹ The principal components on which this regression analysis is based are all mutually orthogonal. This in turn will mean that the condition indices for all regression models based on these principal components will have to be equal to unity. Thus, there can be no issues of multi-collinearity arising from our PCA regression analysis.

regression models vary systematically according to the level of firm profitability. As previously noted, this is an issue that can be addressed by dividing firms into one of three levels of operational efficiency. Given this, we now turn the focus of our attention to the regression results obtained from the three efficiency subsamples formed from our data.

Table 5.10
Total Variance Explained (Full-sample)
N = 9,209

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.378	59.755	59.755	5.378	59.755	59.755	4.889	54.322	54.322
2	2.082	23.132	82.886	2.082	23.132	82.886	2.571	28.564	82.886
3	0.636	7.071	89.957	0.636	7.071	89.957	1.198	13.307	75.548
4	0.478	5.308	95.265	0.478	5.308	95.265	1.115	12.384	87.933
5	0.286	3.179	98.444	0.286	3.179	98.444	0.937	10.411	98.344
6	0.066	0.734	99.179	0.066	0.734	99.179	0.062	0.690	99.034
7	0.050	0.553	99.732	0.050	0.553	99.732	0.061	0.682	99.716
8	0.015	0.167	99.898	0.015	0.167	99.898	0.014	0.159	99.876
9	0.009	0.102	100.000	0.009	0.102	100.000	0.011	0.124	100.000

Table 5.11
Component Matrix (Full-sample)
N = 9,209

Original Variables	Component								
	1	2	3	4	5	6	7	8	9
$x(t)$	0.670	0.337	0.533	-0.335	0.198	-0.043	-0.023	-0.008	0.002
$b(t)$	-0.340	0.736	0.397	0.353	-0.243	-0.009	0.000	-0.002	0.001
$b^2(t)$	-0.531	0.790	-0.189	-0.064	0.154	0.154	-0.076	-0.019	0.001
$x(t)b(t)$	0.934	0.158	0.001	0.242	0.182	0.052	0.033	0.075	-0.037
$x^2(t)$	-0.895	-0.242	0.105	0.234	0.253	-0.051	-0.056	0.035	0.051
$b^3(t)$	-0.518	0.778	-0.283	-0.102	0.085	-0.144	0.089	0.014	-0.003
$b^2(t)x(t)$	0.939	0.072	-0.058	0.265	0.162	0.016	0.087	-0.070	0.031
$b(t)x^2(t)$	-0.930	-0.170	0.221	-0.141	0.019	0.114	0.154	0.017	0.011
$x^3(t)$	0.918	0.281	-0.126	-0.150	-0.182	0.034	0.002	0.048	0.064

Table 5.12
Coefficients Estimate for Components Regressions for Full-sample,
Low-efficiency, Steady-state and High-efficiency Sub-samples

Original High Order Approximation Model: $P(t) = \beta_0 + \beta_1 C(1) + \beta_2 C(2) + \beta_3 C(3) + \beta_4 C(4) + \beta_5 C(5) + \beta_6 C(6) + \beta_7 C(7) + \beta_8 C(8) + \beta_9 C(9) + e(t)$

Valuation Model	Model Coefficients										Model Adjusted R ²	Model F-statistic & DW Value
	t-statistics Listed Below Coefficients											
	β_0	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9		
Full (Firm-Year N = 9,209)	8.2694	0.43815	0.15906	1.4388	2.7802	2.2745	0.7580	0.21919	1.2898	1.7565	41.54%	F=728.108 DW=1.868
	147.7	2.965	0.5855	8.772	17.25	16.09	2.747	0.7035	4.155	8.337		
Low-efficiency (Firm-Year N ₁ = 3,069)	6.6640	0.11438	-0.04468	0.25822	0.73286	0.20178	0.64331	-0.03567	-0.13732	0.07369	5.28%	F=20.014 DW=1.947
	85.47	4.709	-0.4158	4.742	4.813	3.436	3.609	-0.4100	-1.173	0.7492		
Steady-state (Firm-Year N ₂ =3,070)	7.5063	0.87942	2.0469	0.84818	-0.05257	-0.28687	-0.29480	-0.09429	-0.03393	0.20121	25.80%	F=119.565 DW=1.983
	101.5	4.893	23.97	4.929	-0.4869	-2.525	-1.623	-0.7481	-0.2695	1.068		
High-efficiency (Firm-Year N ₂ =3,070)	10.637	4.4030	-0.07658	3.5422	4.6153	0.82361	0.06466	-0.50275	0.72272	-0.96136	57.17%	F=456.199 DW=1.977
	91.56	34.80	-2.142	23.01	13.79	3.233	0.1709	-2.329	2.035	-2.896		

White (1980) adjusted t-statistics are listed below the coefficients. $C(j)$ is the abbreviation for the j^{th} Principal Component.

Variable Definitions: $b(t)$ = Book value of equity per share at the beginning of year t . It represents the book value (proportioned common equity divided by outstanding shares) at the company's fiscal year end, $(t - 1)$ (Datastream mnemonic WC05476). $x(t)$ = Earnings per share for year t . It represents the earnings for the 12 months ended the fiscal year t . Earnings per share is profit after tax, minority interest and preferred dividends but before extraordinary items (Datastream mnemonic WC05201).

5.5.2 PCA on Low-efficiency Sub-sample Data

In this section, PCA is based on the same low-efficiency data as used in section 5.3.2. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy for the low-efficiency sub-sample is 0.709 which again indicates that PCA can be legitimately applied to the low-efficiency sub-sample dataset.³²

Table 5.13 shows that the first and second principal components explain 64.447% and 22.238%, respectively of the total variability in the independent variables. Together these two principal components explain 86.685% of the total variability in the original determining variables. Table 5.14 summarises the factor loadings associated with each of the original determining variables for each of the nine principal components obtained in our analysis. Note how the first principal component loads 0.774 onto the earnings variable, $x(t)$, 0.954 onto the interaction term, $x(t)b(t)$, between earnings and book value, 0.949 onto the interaction term, $b^2(t)x(t)$, between squared book value and earnings and 0.905 onto the cubed value of earnings, $x^3(t)$. Thus, this first principal component may be broadly interpreted as a “non-linear earnings” principal component. Similarly, the second principal component loads heavily onto the book value elements of the vector and may therefore be interpreted as a “non-linear book value” principal component. The third principal component loads heavily and negatively onto the earnings variable, $x(t)$, and may thus be interpreted as a “linear earnings” principal component. In similar vein the fourth principal component loads heavily onto the book value variable, $b(t)$, and may thus be interpreted as a “linear book value” principal component. The remaining principal components are more difficult to interpret and in any event, none of the factor loadings for the fifth and subsequent principal components exceed 0.40 in absolute value.

The results obtained from regressing the market price of equity against the nine principal components obtained from the low-efficiency data are summarised in the second panel of Table 5.12. The coefficients associated with principal components

³² The Bartlett Test of Sphericity statistic amounts to 55,453.51 with 36 degrees of freedom. A test statistic of this magnitude indicates that it is unlikely the sample correlation matrix is compatible with the identity matrix at any of the conventional levels of significance.

1, 3, 4, 5 and 6 are all statistically significant at conventional levels. The adjusted R^2 shows that the nine principal components explain 5.28% of the variability of the contemporaneous market value of equity listed on the SSE in comparison with the adjusted R^2 value of 2.36% generated by the pure linear regression model based on the same dataset but which only includes earnings and book value as explanatory variables (as summarised in Table 5.6 in section 5.3.2). In section 5.4 above we have discussed the issues that might explain the poor explanatory power associated with our regression models based on low efficiency data. However, the increase in explanatory power as one moves from the pure linear model based on earnings and book value alone to the regression model based on the nine principal components shows that the non-linear terms, which proxy for a firm's real option value, play an important role in determining the market value of equity for the low efficiency firms listed on the SSE. Thus it necessarily follows that there is an evident non-linear relationship between the market value of equity and the accounting variables employed in our empirical analysis for low efficiency firms listed on the SSE. Also, the adjusted R^2 value generated by the nine principal components is consistent with the adjusted R^2 value of 5.30% generated by the reduced form non-linear regression model (as summarised in Table 5.6 in section 5.3.2).

Table 5.13
Total Variance Explained (Low-efficiency Sub-sample)
N₁ = 3,069

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.800	64.447	64.447	5.800	64.447	64.447	4.173	46.362	46.362
2	2.001	22.238	86.685	2.001	22.238	86.685	2.213	24.590	70.951
3	0.522	5.798	92.483	0.522	5.798	92.483	1.366	15.176	86.128
4	0.406	4.508	96.990	0.406	4.508	96.990	0.883	9.811	95.938
5	0.173	1.927	98.917	0.173	1.927	98.917	0.262	2.907	98.845
6	0.055	0.609	99.527	0.055	0.609	99.527	0.054	0.605	99.450
7	0.031	0.339	99.866	0.031	0.339	99.866	0.029	0.327	99.777
8	0.010	0.113	99.979	0.010	0.113	99.979	0.018	0.196	99.973
9	0.002	0.021	100.000	0.002	0.021	100.000	0.002	0.027	100.000

Table 5.14
Component Matrix (Low-efficiency Sub-sample)
 $N_1 = 3,069$

Original Variables	Component								
	1	2	3	4	5	6	7	8	9
$x(t)$	0.774	0.257	-0.519	0.122	0.223	-0.013	-0.024	0.000	0.001
$b(t)$	-0.494	0.675	0.174	0.518	-0.004	0.020	-0.009	-0.001	0.000
$b^2(t)$	-0.598	0.733	-0.014	-0.275	0.064	0.157	-0.012	0.007	-0.001
$x(t)b(t)$	0.954	0.100	0.240	-0.026	0.112	0.030	0.046	-0.069	0.013
$x^2(t)$	-0.893	-0.354	0.171	-0.016	0.209	-0.022	-0.059	0.018	0.025
$b^3(t)$	-0.570	0.780	0.015	-0.193	0.033	-0.163	0.040	-0.005	0.001
$b^2(t)x(t)$	0.949	0.047	0.259	0.004	0.142	0.006	0.072	0.065	-0.006
$b(t)x^2(t)$	-0.920	-0.255	-0.249	0.087	-0.013	0.041	0.130	0.003	0.014
$x^3(t)$	0.905	0.363	-0.070	-0.029	-0.205	0.004	-0.017	0.028	0.029

5.5.3 PCA on Steady-state Efficiency Sub-sample Data

In this section, PCA is based on the same steady-state efficiency data as we used in section 5.3.2. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is 0.724 which again indicates that PCA can be legitimately applied to our steady-state efficiency sub-sample dataset.³³

Table 5.15 shows that the first and second principal components explain 86.733% and 7.228% of the total variability in the independent variables, respectively. Together these two principal components explain 93.961% of the total variability in all the independent variables. Table 5.16 summarises the factor loadings associated with each of the original independent variables for each of the nine principal components obtained in our analysis. Note how the first principal component loads heavily onto all of the original variables. Thus, the first principal component may be broadly interpreted as a “benchmark” principal component since it reflects all aspects of the benchmark model derived by Davidson and Tippett (2012) and on which all of our modelling procedures are based. The second principal component loads positively onto earnings and book value with the non-linear and cross product terms mainly having negative loadings which are smaller in absolute terms than those which apply to the earnings and book value variables themselves. Hence, one might label this as a “linear versus non-linear” principal component. The factor loadings associated with the pure book value variables ($b(t)$, $b^2(t)$, $b^3(t)$) in the third principal component are all positive, whilst those associated with earnings and the cross-product terms are predominantly negative. Thus, this third principal component may be interpreted as a “book value versus earnings” principal component. The remaining principal components are more difficult to interpret and in any event, none of the factor loadings for the fourth and subsequent principal components exceed 0.20 in absolute value.

The results obtained from regressing the market price of equity against the nine principal components obtained from the steady-state efficiency data are

³³ The Bartlett Test of Sphericity statistic amounts to 117,166.91 with 36 degrees of freedom. A test statistic of this magnitude indicates that it is unlikely the sample correlation matrix is compatible with the identity matrix at any of the conventional levels of significance.

summarised in the second panel of Table 5.12. The coefficients associated with the principal components 1, 2, 3, and 5 are all statistically significant at conventional levels. The adjusted R^2 shows that the nine principal components explain 25.80% of the variability of the contemporaneous market value of equity of firms listed on the SSE in comparison with the adjusted R^2 value of 25.02% generated by the pure linear regression based on the same dataset but which only includes earnings and book value as explanatory variables (as summarised in Table 5.6 in section 5.3.2). That the regression model based on the nine principal components and the regression model based on book value and earnings alone return insignificantly different R^2 values shows that introducing non-linear terms into the equity valuation process does not appear to bring any particular advantage over the more parsimonious linear model which only includes earnings and book value as explanatory variables. This in turn means that there is a broadly linear relationship between the market value of equity and the accounting (that is, determining) variables for steady-state efficiency firms listed on the SSE.

Table 5.15
Total Variance Explained (Steady-state Sub-sample)
N₂ = 3,070

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.806	86.733	86.733	7.806	86.733	86.733	3.436	38.181	38.181
2	0.651	7.228	93.961	0.651	7.228	93.961	2.910	32.337	70.517
3	0.464	5.150	99.111	0.464	5.150	99.111	2.555	28.387	98.904
4	0.059	0.658	99.769	0.059	0.658	99.769	0.072	0.802	99.706
5	0.014	0.155	99.924	0.014	0.155	99.924	0.017	0.188	99.894
6	0.005	0.054	99.978	0.005	0.054	99.978	0.006	0.062	99.955
7	0.002	0.020	99.998	0.002	0.020	99.998	0.004	0.042	99.998
8	0.000	0.001	100.000	0.000	0.001	100.000	0.000	0.002	100.000
9	1.139E-5	0.000	100.000	1.139E-5	0.000	100.000	1.532E-5	0.000	100.000

Table 5.16
Component Matrix (Steady-state Sub-sample)
 $N_2 = 3,070$

Original Variables	Component								
	1	2	3	4	5	6	7	8	9
$x(t)$	0.876	0.360	-0.288	-0.130	0.044	0.001	-0.013	0.000	0.000
$b(t)$	0.861	0.479	0.092	0.141	0.035	0.001	0.014	0.000	0.000
$b^2(t)$	0.950	0.159	0.261	0.025	-0.054	0.008	-0.025	0.004	0.000
$x(t)b(t)$	0.996	0.057	-0.044	-0.010	-0.053	-0.026	0.002	-0.008	0.000
$x^2(t)$	0.961	-0.027	-0.265	-0.033	-0.054	0.014	0.023	0.005	0.000
$b^3(t)$	0.902	-0.124	0.399	-0.102	0.022	0.029	0.011	-0.002	0.001
$b^2(t)x(t)$	0.963	-0.225	0.139	-0.021	0.028	-0.036	0.004	0.002	-0.002
$b(t)x^2(t)$	0.951	-0.293	-0.075	0.044	0.025	-0.023	-0.004	0.003	0.002
$x^3(t)$	0.913	-0.331	-0.218	0.089	0.018	0.035	-0.011	-0.003	-0.001

5.5.4 PCA on High-efficiency Sub-sample Data

In this section, PCA is based on the same high-efficiency data as we used in section 5.3.2. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy for the high-efficiency sample is 0.630 which again indicates that PCA can be legitimately applied to our high-efficiency sub-sample dataset.³⁴

Table 5.17 shows that the first and second principal components explain 70.467% and 15.966% respectively, of the total variability in the independent variables. Together these two principal components explain 86.433% of the total variability in all the independent variables. Table 5.18 summarises the factor loadings associated with each of the original independent variables for each of the nine principal components obtained in our analysis. Note again how the first principal component loads heavily onto all the original variables. Thus, this first principal component may be broadly interpreted as “benchmark” principal component since it reflects all aspects of the benchmark model derived by Davidson and Tippett (2012) and on which all of our modelling procedures are based. The factor loadings associated with the non-linear pure book value variables ($b^2(t)$, $b^3(t)$) in the second principal component are positive; whilst those associated with earnings and the cross-product terms are predominantly negative. Thus, this second principal component may be interpreted as a “book value versus earnings” principal component. The third principal component loads positively onto earnings and book value with the non-linear and cross product terms mainly having negative loadings which are smaller in absolute terms than those which apply to the earnings and book value variables. Hence, one might label this as a “linear versus non-linear” principal component. The remaining principal components are more difficult to interpret and in any event, none of the factor loadings for the fourth and subsequent principal components exceed 0.30 in absolute value.

The regression results based on the nine principal components are summarised in the fourth panel of Table 5.12. The coefficients associated with all components,

³⁴ The Bartlett Test of Sphericity statistic amounts to 96,260.42 with 36 degrees of freedom. A test statistic of this magnitude indicates that it is unlikely the sample correlation matrix is compatible with the identity matrix at any of the conventional levels of significance.

except component 6, are statistically significant. The adjusted R^2 shows that the nine components which capture all information embedded in the original variables explain 57.17% of the variability of the contemporaneous market value of equity listed on the SSE. Recall here that based on the same high-efficiency sample dataset, the adjusted R^2 value generated by the pure linear equity valuation model with only earnings and book value as explanatory variables is 49.63% (as summarised in Table 5.6 in section 5.3.1). The substantial increase in the explanatory power shows that the non-linear terms which proximate a firm's real option value play an important role in determining the market value of equity for firms with high efficiency. Thus it necessarily follows that there is an evident non-linear relationship between the market value of equity and accounting variables for high-efficiency firms listed on the SSE. The adjusted R^2 value generated by the nine components is also compatible with the adjusted R^2 value of 55.14% generated by the reduced form non-linear regression (as summarised in Table 5.6 in section 5.3.2).

Table 5.12 also presents the Durbin-Watson statistics associated with each regression model. For all three regressions based on the subsample datasets the Durbin-Watson statistics cluster around their expected value of two, thereby confirming that there are no significant problems with autocorrelated residuals in our regression models. Thus classifying firms into one of three groups based on their operational efficiency addresses the issue of serial correlation that emerged with our regression procedures based on the pooled data. Moreover, all F-statistics are statistically significant at any reasonable level thereby confirming that one can reject the maintained hypothesis that $R^2 = 0$ for all three regressions.

Table 5.17
Total Variance Explained (High-efficiency Sub-sample)
N₃ = 3,070

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.342	70.467	70.467	6.342	70.467	70.467	3.279	36.429	36.429
2	1.437	15.966	86.433	1.437	15.966	86.433	3.253	36.148	72.578
3	0.991	11.007	97.439	0.991	11.007	97.439	1.399	15.544	88.122
4	0.192	2.134	99.573	0.192	2.134	99.573	1.020	11.334	99.455
5	0.027	0.300	99.874	0.027	0.300	99.874	0.034	0.373	99.828
6	0.006	0.071	99.944	0.006	0.071	99.944	0.009	0.101	99.929
7	0.005	0.051	99.995	0.005	0.051	99.995	0.006	0.064	99.993
8	0.000	0.004	100.000	0.000	0.004	100.000	0.001	0.007	99.999
9	4.490E-5	0.000	100.000	4.490E-5	0.000	100.000	5.295E-5	0.001	100.000

Table 5.18
Component Matrix (High-efficiency Sub-sample)
N₃ = 3,070

Original Variables	Component								
	1	2	3	4	5	6	7	8	9
$x(t)$	0.733	-0.255	0.565	-0.275	0.046	-0.020	0.006	0.000	0.000
$b(t)$	0.713	0.177	0.618	0.278	0.034	0.014	-0.013	0.000	0.000
$b^2(t)$	0.875	0.479	0.025	0.023	-0.046	0.000	.052	-0.004	0.000
$x(t)b(t)$	0.993	-0.007	0.037	0.008	-0.107	-0.030	-0.019	0.009	0.000
$x^2(t)$	0.867	-0.487	-0.025	-0.074	-0.049	0.060	-0.006	-0.003	0.000
$b^3(t)$	0.748	0.610	-0.229	-0.106	0.056	0.022	-0.010	0.009	0.002
$b^2(t)x(t)$	0.907	0.322	-0.266	-0.043	0.026	-0.005	-0.019	-0.008	-0.004
$b(t)x^2(t)$	0.915	-0.266	-0.293	0.076	0.022	-0.028	-0.012	-0.008	0.004
$x^3(t)$	0.760	-0.572	-0.278	0.118	0.059	-0.004	0.026	0.008	-0.002

5.6 Conclusion

The empirical analysis summarised in this chapter shows that there is a strong non-linear relationship between the market value of equity for firms listed on the SSE and the accounting information appearing in their financial statements. In particular, when the pooled sample data are partitioned into low-efficiency, steady-state efficiency and high-efficiency subsample data, these empirical results are compatible with the real option hypothesis and evidence a highly non-linear relationship between the market value of equity and the accounting (that is, determining) variables. For low-efficiency firms the liquidation option value makes a significant contribution to the overall market value of equity. For high-efficiency firms growth option value makes a significant contribution to the overall market value of equity. For steady-state firms real option value is negligible and thus the relationship between the market value of equity and the accounting (that is, determining) variables is approximately linear - consistent with Ohlson (1995) model.

The PCA results summarised in the latter sections of this chapter are compatible with the results generated by the non-linear regression procedures invoked in the early part of the chapter. The overall tenor of our empirical analysis is that non-linear equity valuation models provide a more compelling explanation of the relationship between the market value of equity and its determining variables than the purely linear models one normally encounters in the empirical literature of the area. The fact that there is a substantial increase in the adjusted R^2 values as one moves from the pure linear models based on earnings and book value alone to regression models that incorporate non-linear terms provides compelling evidence that firms are not homogeneous in terms of the circumstances they face and that the real options available to them have non-trivial values - particularly in the case of the low-efficiency and high-efficiency firms comprising our sample data.

APPENDIX
Complete Derivation of the Power Series Expansion for the Ashton, Cooke and Tippet (2003) Equity Valuation Model

Suppose we follow the text of this chapter in defining η to be the recursion value of equity [as given by equation (5.1)]. Moreover, one can let i be the cost of the firm's equity capital in which case it follows that the market value of equity will have to satisfy the following no-arbitrage condition:

$$P(\eta(t)) = e^{-idt} E_t[P(\eta(t + dt))]$$

where $E_t(\cdot)$ is the expectations operator taken at time t . Ashton et al., (2003, pp. 431-434) show that this no-arbitrage condition has a one to one and onto mapping into the following linear differential equation:

$$\frac{1}{2}\zeta^2\eta\frac{d^2P}{d\eta^2} + i\eta\frac{dP}{d\eta} - iP(\eta) = 0$$

where ζ^2 is the variance parameter associated with the white noise term in the recursion value of equity (as in section 3.2 of this dissertation). Moreover, Davidson and Tippet (2012, pp. 221-223) show that the unique solution of this differential equation under the boundary conditions prescribed in section 3.5 of this dissertation is given by:

$$P(\eta) = \eta + \frac{P(0)}{2} \int_{-1}^1 \exp\left(\frac{-2\theta\eta}{1+z}\right) dz$$

where $P(0)$ is the adaptation value of the firm's equity when the firm's recursion value falls away to nothing (Davidson & Tippet, 2012, pp. 273-274) and $\theta = \frac{2i}{\zeta^2}$ is a measure of the relative stability with which the recursion value of equity grows over time. We now demonstrate the procedures associated with determining the power series expansion for $P(\eta)$ by assuming (without loss of generality) that $P(0) = 1$ is the value of the firm's adaptation options when the recursion value

of equity falls away to nothing. It then follows that the Fourier-Laguerre coefficients, α_m , are determined by minimising the weighted least squares integral:

$$\int_0^{\infty} e^{-\eta} [P(\eta) - \sum_{m=0}^{\infty} \alpha_m L_m(\eta)]^2 d\eta$$

Differentiating under the integral sign with respect to α_j for $j = 1, 2, 3, \dots$ will then show:

$$\int_0^{\infty} e^{-\eta} [P(\eta) - \sum_{m=0}^{\infty} \alpha_m L_m(\eta)] L_j(\eta) d\eta = 0$$

defines the abscissa of a global minimum in the weighted least squares integral. It is well known, however, that the Laguerre polynomials are orthonormal with respect to the weighting function $e^{-\eta}$ (Carnahan et al., 1969, p. 100). This in turn will mean:

$$\int_0^{\infty} e^{-\eta} \sum_{m=0}^{\infty} \alpha_m L_m(\eta) L_j(\eta) d\eta = \alpha_j$$

Hence, the Fourier coefficients, α_j , for the equity valuation function with respect to the Laguerre polynomial of order j , $L_j(\eta)$, will be:

$$\alpha_j = \int_0^{\infty} e^{-\eta} P(\eta) L_j(\eta) d\eta$$

One can use this expression to determine the Fourier coefficient, α_0 , associated with the Laguerre polynomial of order zero; namely:

$$\alpha_0 = \int_0^{\infty} e^{-\eta} P(\eta) L_0(\eta) d\eta = \int_0^{\infty} e^{-\eta} \left[\eta + \frac{1}{2} \int_{-1}^1 \exp\left(\frac{-2\theta\eta}{1+z}\right) dz \right] d\eta$$

The above expression may be decomposed into two integrals, the first of which

is $\int_0^{\infty} \eta e^{-\eta} d\eta = 1$. For the second component, note that all functions under the

integral sign are continuous in which case it follows:

$$\frac{1}{2} \int_0^{\infty} \int_{-1}^1 e^{-\eta} \exp\left(\frac{-2\theta\eta}{1+z}\right) dz d\eta = \frac{1}{2} \int_{-1}^1 \int_0^{\infty} \exp\left[\frac{-(2\theta + (1+z))\eta}{1+z}\right] d\eta dz$$

where Fubini's Theorem allows the order of integration to be reversed. One can then evaluate this double integral as follows (Thomas and Finney, 1996, p. 919):

$$\frac{1}{2} \int_{-1}^1 \int_0^{\infty} \exp\left[\frac{-(2\theta + (1+z))\eta}{1+z}\right] d\eta dz = \frac{1}{2} \int_{-1}^1 \frac{(1+z)}{(2\theta + (1+z))} dz = \theta \log\left(\frac{\theta}{1+\theta}\right) + 1$$

It then follows:³⁵

³⁵ We here impose the requirement that $P(0) = 1$ or that the adaptation value of the firm's equity when the firm's recursion value falls away to nothing has a unit value (Davidson & Tippett, 2012, pp. 273-274). Without this assumption the Fourier coefficient determined here would take the alternative value:

$$\alpha_0 = \int_0^{\infty} e^{-\eta} P(\eta) L_0(\eta) d\eta = 1 + P(0) \left[\theta \log\left(\frac{\theta}{1+\theta}\right) + 1 \right]$$

Hence, the more general case complicates the algebra without adding anything of significance to the analytical arguments on which my empirical analysis is based.

$$\alpha_0 = \int_0^{\infty} e^{-\eta} P(\eta) L_0(\eta) d\eta =$$

$$\int_0^{\infty} \eta e^{-\eta} d\eta + \frac{1}{2} \int_{-1}^1 \int_0^{\infty} \exp\left[-\frac{(2\theta + (1+z))\eta}{1+z}\right] d\eta dz = \theta \log\left(\frac{\theta}{1+\theta}\right) + 2$$

Appropriate substitution will also show that the Fourier coefficient, α_1 , associated with the Laguerre polynomial of order zero will be:

$$\alpha_1 = \int_0^{\infty} e^{-\eta} P(\eta) L_1(\eta) d\eta = \int_0^{\infty} e^{-\eta} \left[\eta + \frac{1}{2} \int_{-1}^1 \exp\left(\frac{-2\theta\eta}{1+z}\right) dz \right] (1 - \eta) d\eta$$

Note, however, that the expression for a_1 may be decomposed into three integrals,

the first of which is $\int_0^{\infty} (\eta - \eta^2) e^{-\eta} d\eta = -1$. Moreover, we know from earlier analysis

in this Appendix that:

$$\frac{1}{2} \int_{-1}^1 \int_0^{\infty} \exp\left[-\frac{(2\theta + (1+z))\eta}{1+z}\right] d\eta dz = \frac{1}{2} \int_{-1}^1 \frac{(1+z)}{(2\theta + (1+z))} dz = \theta \log\left(\frac{\theta}{1+\theta}\right) + 1$$

For the third component, note that all functions under the integral sign are continuous in which case we can again apply Fubini's Theorem to give (Thomas and Finney, 1996, p. 919):

$$\frac{1}{2} \int_0^{\infty} \int_{-1}^1 \eta e^{-\eta} \exp\left(\frac{-2\theta\eta}{1+z}\right) dz d\eta = \frac{1}{2} \int_{-1}^1 \int_0^{\infty} \eta \exp\left[\frac{-(2\theta + (1+z))\eta}{(1+z)}\right] d\eta dz$$

Moreover, one can then evaluate this double integral as follows:

$$\frac{1}{2} \int_{-1}^1 \int_0^{\infty} \eta \exp\left[\frac{-(2\theta + (1+z))\eta}{(1+z)}\right] d\eta dz = \frac{1}{2} \int_{-1}^1 \left[\frac{1+z}{2\theta + (1+z)}\right]^2 dz = (1+\theta) - \frac{\theta^2}{1+\theta} + 2\theta \log\left(\frac{\theta}{1+\theta}\right)$$

It then follows:

$$\begin{aligned} \alpha_1 &= \int_0^{\infty} e^{-\eta} P(h) L_1(\eta) d\eta = \int_0^{\infty} e^{-\eta} (\eta - \eta^2) d\eta + \frac{1}{2} \int_{-1}^1 \int_0^{\infty} (1-\eta) \exp\left[\frac{-(2\theta\eta + (1+z)\eta)}{1+z}\right] d\eta dz = \\ &= -1 + [\theta \log\left(\frac{\theta}{1+\theta}\right) + 1] - [(1+\theta) - \frac{\theta^2}{1+\theta} + 2\theta \log\left(\frac{\theta}{1+\theta}\right)] \end{aligned}$$

After collecting and cancelling terms the above expression reduces to:

$$\alpha_1 = \frac{\theta^2}{1+\theta} - (1+\theta) - \theta \log\left(\frac{\theta}{1+\theta}\right) = \frac{\theta^2 - (1+\theta)^2}{(1+\theta)} - \theta \log\left(\frac{\theta}{1+\theta}\right)$$

Simplifying the first term on the far right hand side of this expression shows:

$$\alpha_1 = -\frac{1+2\theta}{(1+\theta)} - \theta \log\left(\frac{\theta}{1+\theta}\right) = -\left[2 - \frac{1}{(1+\theta)}\right] - \theta \log\left(\frac{\theta}{1+\theta}\right)$$

This latter expression can in turn be simplified to:

$$\alpha_1 = -\left[2 - \frac{1}{(1+\theta)}\right] - \theta \log\left(\frac{\theta}{1+\theta}\right) = -\left[1 + 1 - \frac{1}{(1+\theta)}\right] - \theta \log\left(\frac{\theta}{1+\theta}\right)$$

or equivalently:³⁶

$$\alpha_1 = -[1 + \frac{\theta}{(1 + \theta)}] - \theta \log(\frac{\theta}{1 + \theta}) = -1 - \frac{\theta}{(1 + \theta)} - \theta \log(\frac{\theta}{1 + \theta})$$

For the general case, appropriate substitution will show:

$$\alpha_m = \int_0^{\infty} e^{-\eta} P(\eta) L_m(\eta) d\eta =$$

$$\int_0^{\infty} e^{-\eta} [C_0^m - C_1^m \cdot \eta + C_2^m \cdot \frac{\eta^2}{2!} - C_3^m \cdot \frac{\eta^3}{3!} + \dots + (-1)^m C_m^m \cdot \frac{\eta^m}{m!}] [\eta + \frac{1}{2} \int_{-1}^1 \exp(\frac{-2\theta\eta}{1+z}) dz] d\eta$$

Now, this can be split into two integrals the first of which is as follows:

$$\int_0^{\infty} \eta e^{-\eta} [C_0^m - C_1^m \cdot \eta + C_2^m \cdot \frac{\eta^2}{2!} - C_3^m \cdot \frac{\eta^3}{3!} + \dots + (-1)^m C_m^m \cdot \frac{\eta^m}{m!}] d\eta$$

Or equivalently:

$$\int_0^{\infty} e^{-\eta} [C_0^m \cdot \frac{\eta}{0!} - C_1^m \cdot \frac{\eta^2}{1!} + C_2^m \cdot \frac{\eta^3}{2!} - C_3^m \cdot \frac{\eta^4}{3!} + \dots + (-1)^m C_m^m \cdot \frac{\eta^{m+1}}{m!}] d\eta$$

³⁶ We have previously noted how the Fourier coefficient determined here is based on the assumption that $P(0) = 1$. Under the more general case of a non-unit value for $P(0)$, the Fourier coefficient becomes:

$$\alpha_1 = \int_0^{\infty} e^{-\eta} P(h) L_1(\eta) d\eta = -1 + [\theta \log(\frac{\theta}{1 + \theta}) + 1] - P(0)[(1 + \theta) - \frac{\theta^2}{1 + \theta} + 2\theta \log(\frac{\theta}{1 + \theta})]$$

This again shows that the more general case complicates the algebra without adding anything of significance to the analytical arguments on which my empirical analysis is based.

Now consider the kth term in the above expression:

$$\int_0^{\infty} C_k^m \cdot \frac{\eta^{k+1}}{k!} e^{-\eta} d\eta = \frac{m!}{(k!)^2(m-k)!} \int_0^{\infty} \eta^{k+1} e^{-\eta} d\eta = \frac{m! \Gamma(k+2)}{(k!)^2(m-k)!}$$

where $\Gamma(k) = \int_0^{\infty} \eta^{k-1} e^{-\eta} d\eta = (k-1)!$ is the gamma function of mathematical

statistics. It follows from this that:

$$\int_0^{\infty} C_k^m \cdot \frac{\eta^{k+1}}{k!} e^{-\eta} d\eta = \frac{m! \Gamma(k+2)}{(k!)^2(m-k)!} = \frac{m!(k+1)!}{(k!)^2(m-k)!} = (k+1) \cdot \frac{m!}{k!(m-k)!} = (k+1)C_k^m$$

The first integral can thus be evaluated as:

$$\int_0^{\infty} e^{-\eta} [C_0^m \cdot \frac{\eta}{0!} - C_1^m \cdot \frac{\eta^2}{1!} + C_2^m \cdot \frac{\eta^3}{2!} - C_3^m \cdot \frac{\eta^4}{3!} + \dots + (-1)^m C_m^m \cdot \frac{\eta^{m+1}}{m!}] d\eta = \sum_{k=0}^m (-1)^k (k+1) C_k^m$$

Now, from the binomial theorem we know (Apostol, 1967, p.44):

$$\sum_{k=0}^m C_k^m x^k = (1+x)^m$$

Moreover, one can differentiate through the above expression and thereby show:

$$\frac{d}{dx} \left[\sum_{k=0}^m C_k^m x^k \right] = \sum_{k=0}^m k C_k^m x^{k-1} = m(1+x)^{m-1} = \frac{d}{dx} [(1+x)^m]$$

Multiplying both sides of the above expression by x then shows:

$$\sum_{k=0}^m k C_k^m x^k = mx(1+x)^{m-1}$$

Hence, these latter two results imply:

$$\sum_{k=0}^m C_k^m x^k + \sum_{k=0}^m k C_k^m x^k = (1+x)^m + mx(1+x)^{m-1}$$

or equivalently:

$$\sum_{k=0}^m (1+k) C_k^m x^k = (1+x)^{m-1} [1 + (m+1)x]$$

Letting $x = -1$ in the above expression then shows:

$$\sum_{k=0}^m (1+k) C_k^m (-1)^k = 0$$

provided $m \geq 2$. Using this result we thus have:

$$\int_0^\infty e^{-\eta} [C_0^m \cdot \frac{\eta}{0!} - C_1^m \cdot \frac{\eta^2}{1!} + C_2^m \cdot \frac{\eta^3}{2!} - C_3^m \cdot \frac{\eta^4}{3!} + \dots + (-1)^m C_m^m \cdot \frac{\eta^{m+1}}{m!}] d\eta =$$

$$\sum_{k=0}^m (-1)^k (k+1) C_k^m = 0$$

when $m \geq 2$. One can now return to the second integral which may be evaluated as:

$$\frac{1}{2} \int_0^\infty \int_{-1}^1 e^{-\eta} [C_0^m - C_1^m \cdot \eta + C_2^m \cdot \frac{\eta^2}{2!} - C_3^m \cdot \frac{\eta^3}{3!} + \dots + (-1)^m C_m^m \cdot \frac{\eta^m}{m!}] \exp\left(\frac{-2\theta\eta}{1+z}\right) dz d\eta =$$

$$\frac{1}{2} \int_0^{\infty} \int_{-1}^1 [C_0^m - C_1^m \cdot \eta + C_2^m \cdot \frac{\eta^2}{2!} - C_3^m \cdot \frac{\eta^3}{3!} + \dots + (-1)^m C_m^m \cdot \frac{\eta^m}{m!}] \exp\left[-\frac{(2\theta + (1+z))\eta}{1+z}\right] d\eta dz$$

One can again apply Fubini's Theorem to reverse the order of integration in the above expression give (Thomas and Finney, 1996, p. 919):

$$\frac{1}{2} \int_{-1}^1 \int_0^{\infty} [C_0^m - C_1^m \cdot \eta + C_2^m \cdot \frac{\eta^2}{2!} - C_3^m \cdot \frac{\eta^3}{3!} + \dots + (-1)^m C_m^m \cdot \frac{\eta^m}{m!}] \exp\left[-\frac{(2\theta + (1+z))\eta}{1+z}\right] d\eta dz$$

To evaluate this integral we first make the substitution $y = \frac{(2\theta + (1+z))\eta}{1+z}$

or $\eta = \frac{(1+z)y}{2\theta + (1+z)}$ and $d\eta = \frac{1+z}{2\theta + (1+z)} dy$. This enables one to restate the first component of the above integral as:

$$\int_0^{\infty} [C_0^m - C_1^m \cdot \eta + C_2^m \cdot \frac{\eta^2}{2!} - C_3^m \cdot \frac{\eta^3}{3!} + \dots + (-1)^m C_m^m \cdot \frac{\eta^m}{m!}] \exp\left[-\frac{(2\theta + (1+z))\eta}{1+z}\right] d\eta =$$

$$\frac{1+z}{2\theta + (1+z)} \int_0^{\infty} \left\{ C_0^m - C_1^m \cdot \frac{(1+z)y}{2\theta + (1+z)} + \dots + (-1)^m \frac{C_m^m}{m!} \cdot \left[\frac{(1+z)y}{2\theta + (1+z)} \right]^m \right\} e^{-y} dy$$

Now consider the kth term in the above expression:

$$\frac{1+z}{2\theta + (1+z)} \int_0^{\infty} \frac{C_k^m}{k!} \cdot \left[\frac{(1+z)y}{2\theta + (1+z)} \right]^k e^{-y} dy = \frac{C_k^m}{k!} \left[\frac{(1+z)}{2\theta + (1+z)} \right]^{k+1} \int_0^{\infty} y^k e^{-y} dy =$$

$$C_k^m \left[\frac{(1+z)}{2\theta + (1+z)} \right]^{k+1}$$

It thus follows from previous results that:

$$\frac{1+z}{2\theta + (1+z)} \int_0^\infty \left\{ C_0^m - C_1^m \frac{(1+z)y}{2\theta + (1+z)} + \dots + (-1)^m \frac{C_m^m}{m!} \left[\frac{(1+z)y}{2\theta + (1+z)} \right]^m \right\} e^{-y} dy =$$

$$\sum_{k=0}^m (-1)^k C_k^m \left[\frac{(1+z)}{2\theta + (1+z)} \right]^{k+1}$$

Now suppose one lets $x = \frac{(1+z)}{2\theta + (1+z)}$. Then from previous analysis one may evaluate the above integral as:

$$\sum_{k=0}^m (-1)^k C_k^m x^{k+1} = x(1-x)^m = \left[\frac{(1+z)}{2\theta + (1+z)} \right] \left[1 - \frac{(1+z)}{2\theta + (1+z)} \right]^m = \frac{(2\theta)^m (1+z)}{[2\theta + (1+z)]^{m+1}}$$

It then follows that the second component of the double integral given earlier will be:

$$\frac{(2\theta)^m}{2} \int_{-1}^1 \frac{(1+z)dz}{[2\theta + (1+z)]^{m+1}}$$

If, however, one makes the substitutions $x = (1+z)$ and $dx = dz$, the above integral reduces to:

$$\frac{(2\theta)^m}{2} \int_{-1}^1 \frac{(1+z)dz}{[2\theta + (1+z)]^{m+1}} = \frac{(2\theta)^m}{2} \int_0^2 \frac{x dx}{(2\theta + x)^{m+1}}$$

Applying integration by parts then shows:

$$\frac{(2\theta)^m}{2} \int_0^2 \frac{x dx}{(2\theta + x)^{m+1}} = \frac{(2\theta)^m}{2} \left[\frac{-x}{m(2\theta + x)^m} + \frac{1}{m} \int \frac{dx}{(2\theta + x)^m} \right]_0^2$$

or, upon evaluating the integral on the right hand side of this latter expression:

$$\frac{(2\theta)^m}{2} \int_0^2 \frac{x dx}{(2\theta + x)^{m+1}} = \frac{(2\theta)^m}{2} \left[\frac{-x}{m(2\theta + x)^m} + \frac{1}{m(1-m)(2\theta + x)^{m-1}} \right]_0^2$$

This, in turn, reduces to:

$$\frac{(2\theta)^m}{2} \int_0^2 \frac{x dx}{(2\theta + x)^{m+1}} = \frac{(2\theta)^m}{2} \left[\frac{-2(1-m)}{m(1-m)(2\theta + 2)^m} + \frac{(2\theta + 2)}{m(1-m)(2\theta + 2)^m} - \frac{1}{m(1-m)(2\theta)^{m-1}} \right]$$

Upon collecting and cancelling terms we then have:

$$\frac{(2\theta)^m}{2} \int_0^2 \frac{x dx}{(2\theta + x)^{m+1}} = \frac{(2\theta)^m}{2} \left[\frac{2(m+\theta)(2\theta)^{m-1}}{m(1-m)(2\theta + 2)^m (2\theta)^{m-1}} - \frac{(2\theta + 2)^m}{m(1-m)(2\theta + 2)^m (2\theta)^{m-1}} \right]$$

or equivalently:

$$\alpha_m = \frac{(2\theta)^m}{2} \int_0^2 \frac{x dx}{(2\theta + x)^{m+1}} = \frac{\theta(1+\theta)^m - (m+\theta)\theta^m}{m(m-1)(1+\theta)^m}$$

which is equation (5.5) of the text.³⁷

Now, the power series expansion of the Ashton et al., (2003) equity valuation model will thus be:

$$P(\eta) = \sum_{m=0}^{\infty} \alpha_m L_m(\eta) = \alpha_0 L_0(\eta) + \alpha_1 L_1(\eta) + \alpha_2 L_2(\eta) + \alpha_3 L_3(\eta) + \dots$$

Here we can use the fact that the first four Laguerre polynomials are $L_0(\eta) = 1$,

$$L_1(\eta) = 1 - \eta, \quad L_2(\eta) = \frac{1}{2}(\eta^2 - 4\eta + 2) \quad \text{and} \quad L_3(\eta) = \frac{1}{6}(-\eta^3 + 9\eta^2 - 18\eta + 6).$$

Moreover, we have also shown that:

$$\alpha_0 = \theta \log\left(\frac{\theta}{1 + \theta}\right) + 2$$

$$\alpha_1 = -1 - \frac{\theta}{(1 + \theta)} - \theta \log\left(\frac{\theta}{1 + \theta}\right)$$

$$\alpha_2 = \frac{\theta(1 + \theta)^2 - (2 + \theta)\theta^2}{2(2 - 1)(1 + \theta)^2} = \frac{\theta}{2(1 + \theta)^2}$$

$$\alpha_3 = \frac{\theta(1 + \theta)^3 - (3 + \theta)\theta^3}{3(3 - 1)(1 + \theta)^3} = \frac{\theta + 3\theta^2}{6(1 + \theta)^3}$$

Substitution will then show that the market price of the firm's equity will be:

³⁷ We have previously noted how the Fourier coefficient determined here is based on the assumption that $P(0) = 1$. Under the more general case of a non-unit value for $P(0)$, the Fourier coefficient becomes:

$$\alpha_m = \int_0^{\infty} e^{-\eta} P(\eta) L_m(\eta) d\eta = P(0) \left[\frac{\theta(1 + \theta)^m - (m + \theta)\theta^m}{m(m - 1)(1 + \theta)^m} \right]$$

This again shows that the more general case merely complicates the algebra without adding anything of significance to the analytical arguments on which my empirical analysis is based.

$$\begin{aligned}
P(\eta) = & [\theta \log(\frac{\theta}{1+\theta}) + 2].1 + [-1 - \frac{\theta}{(1+\theta)} - \theta \log(\frac{\theta}{1+\theta})].(1 - \eta) + \\
& + [\frac{\theta}{4(1+\theta)^2}].(\eta^2 - 4\eta + 2) + [\frac{\theta + 3\theta^2}{36(1+\theta)^3}].(-\eta^3 + 9\eta^2 - 18\eta + 6) + e_3(\eta)
\end{aligned}$$

where $e_3(\eta)$ is an error term representing all the higher order terms that have been omitted from the power series expansion. Using the standard series expression for the Laguerre polynomials in conjunction with the expression for the Fourier coefficients derived earlier in this Appendix shows that the error expression has the following series representation (Abramowitz and Stegun, 1972):

$$e_3(\eta) = \sum_{m=4}^{\infty} \sum_{p=1}^m \frac{\theta(1+\theta)^m - (m+\theta)\theta^m}{m(m-1)(1+\theta)^m} \cdot \frac{(-1)^p}{p!} \cdot \frac{m!}{p!(m-p)!} \cdot \eta^p$$

Moreover, one can substitute the expression for the recursion value of equity given in equation (5.1) of the text into the third order power series expansion given above and thereby derive the third order approximation to the market value of equity stated in terms of book value, $b(t)$, and earnings, $x(t)$, as summarised in equation (5.7) of the text.

Chapter 6

Conclusion

6.1 Summary and Main Findings

The distinguishing feature of modern equity valuation theory is that equity values must be determined within the context of uncertain future cash flows. It was Rubinstein (1976) who formulated a general state-preference based model of the valuation of uncertain income streams and it is this which forms the foundation for the development of the residual income equity valuation (RIV) model that lies at the heart of all the empirical analysis summarised in this dissertation. We show in particular that the present value of a firm's expected future operating cash flows (or the present value of the firm's equity) is equal to the current book value of the firm's equity plus the present value of the expected future residual (that is, abnormal) income stream. The RIV model opens up a direct link between the information appearing in a firm's financial statements and the fundamental (or intrinsic) value of the firm's equity (Kay, 1976; Peasnell, 1982)

The Ohlson (1995) equity valuation model, which is developed from the RIV model, is formulated in terms of a first order vector system of stochastic differential equations. This system of stochastic differential equations involves two variables. First, there is the firm's abnormal (or residual) income which is stated in terms of a first order mean-reversion process. Second, there is the other information variable which encompasses all relevant valuation information that has not, as yet, been recorded in the firm's bookkeeping records. The information variable also evolves in terms of a first order mean reversion process - although increments in the information variable may have a non-trivial correlation with increments in the residual income variable. The Ohlson (1995) model shows that the market value of equity can be determined as a linear combination of the current book value of equity, the current value of the firm's abnormal earnings and the current value of the information variable (Ashton et al., 2003). Unfortunately, empirical applications of the Ohlson (1995) model show that it significantly

underestimates equity values, suffers from internal inconsistencies and has no particular advantage in terms of explanatory power over more parsimonious models based on earnings and/or dividend capitalisation alone. Moreover, other empirical evidence in this area documents a potentially highly non-linear relationship between the market value of a firm's equity and the accounting information appearing in the firm's financial statements.

The non-linearities which appear to exist in equity valuation raise concerns about the validity of the linear models which normally underscore empirical work in this area of the literature. The analysis summarised in this dissertation shows, for example, that abandonment option value is the predominant determinant of the market value of equity for firms with low operational efficiency. Here it is well known that option values are non-linear in their determining variables and so, one would expect there to be a highly non-linear relationship between equity values and their determining variables for firms with low operational efficiency. Burgstahler and Dichev (1997) amongst others argue that abandonment option value will be closely associated with the book value of equity and so it is hardly surprising that the empirical evidence shows that for firms with low operational efficiency there is a statistically significant and non-linear relationship between equity values and the book value of equity. This contrasts with firms with high operational efficiency for which growth option value makes a significant contribution to the overall market value of equity. Thus, for high-efficiency firms, earnings is the more important determining factor in the equity valuation process.

How real option values can be included in the equity valuation process has been summarised in detail by Ashton et al. (2003), the Zhang (2000) and Yee (2000). All three models developed in these papers are compatible with the empirical evidence to varying degrees and show that the market value of equity possesses a non-linear relationship with the earnings and book value figures appearing in corporate financial statements. Real option value will normally comprise a significant proportion of the overall market value of the firm's equity and in particular, for low-efficiency and highly profitable firms. Here, the Ashton et al. (2003) model is developed in continuous time and provides a closed-form solution

for the adaptation value and the overall market value of a firm's equity. This contrasts with both the Zhang (2000) and Yee (2000) models for which closed form solutions are not available. Since the closed form solution provided by the Ashton et al. (2003) model facilitates the empirical analysis of the non-linear relationship which appears to exist between equity values and its determining variables, it is this model which is applied in the empirical analysis conducted in this dissertation.

The non-linear relationship which appears to exist between the market value of equity and the accounting variables that appear in corporate financial statements raises the distinct possibility of a correlated omitted variables problem in the primarily linear equity valuation models that underscore most of the empirical work summarised in this area of the literature. Other possible omitted factors have also been discussed in this dissertation; in particular, the momentum and acceleration of the variables comprising a firm's investment opportunity set. Here, our empirical analysis shows that the momentum of the variables comprising a firm's investment opportunity set can, in particular, have a significant impact on the market value of the firm's equity. Given the omitted variable problems that are pervasive in this area of the literature, the empirical tests in this dissertation answer two main research questions: first, do earnings momentum and earnings acceleration have an impact on the market value of equity? Second, do non-linear terms - the proxy for real option value - have an impact on the market value of equity? Although these two research questions could be considered separately, they are integrated within this dissertation.

The first part of the empirical work summarised in this dissertation assesses the impact that earnings momentum and earnings acceleration have on the market value of equity for firms listed on the Shanghai Stock Exchange (SSE). The empirical analysis in this part of the dissertation covers the period from 1999 until 2012 but is also replicated over the shorter period from 2005 until 2012 in order to check the robustness of the results we report for the entire sample. The empirical analysis is based on the Davidson and Tippett (2012) equity valuation model which shows that if a firm's investment opportunity set can be stated in terms of a higher order system of stochastic differential equations, then earnings momentum and/or

earnings acceleration have the potential to make a significant contribution to the overall market value of a firm's equity.

The empirical analysis summarised in the dissertation shows that neither earnings momentum nor earnings acceleration exhibit a significant impact on the market value of equity for the pooled sample data on which the empirical analysis is based. However, when the pooled data are divided into three equally numerous groups based on each firm's operational efficiency, the t-statistic associated with earnings momentum for steady-state firms becomes significant. This contrasts with the t-statistics associated with earnings momentum for low-efficiency and high-efficiency firms, both of which are insignificantly different from zero. However, here it needs to be emphasised that the incremental explanatory power of the earnings momentum variable for steady-state firms is just above one percentage point. Whilst this shows that earnings momentum can impact on equity values, its effect is minimal in explanatory terms and adds very little to the parsimonious regression model based on earnings and book value alone. Furthermore, the coefficients associated with earnings acceleration in all three efficiency level regressions were insignificantly different from zero. This shows that earnings acceleration does not appear to impact on equity values. Moreover, the empirical results do not show significant differences between the sample data selected from the different time periods; that is, the period from 1999 until 2012 and the shorter period from 2005 until 2012.

One potential reason why earnings momentum and earnings acceleration appear to have such minimal impact on the market value of equity stocks listed on the SSE is that they cannot capture the non-linear effects that arise from a firm's ability to modify or even completely abandon its existing investment opportunity set. Hence, this study includes the non-linear terms, which proxy for real option value in the valuation process, and examines how real option value impacts on the market value of equity. Here we follow Davidson and Tippett (2012) who expand the Ashton et al. (2003) equity valuation formula in terms of an infinite power series based on the Laguerre polynomials. In doing this, the Ashton et al. (2003) non-linear equity valuation model is developed into an empirically implementable form that is used

as a benchmark model in all of the empirical analysis summarised in the dissertation.

Unfortunately, due to the multi-collinearity problem, the polynomial expansion for the original Davidson and Tippett (2012) model cannot be directly applied to the data on which the empirical analysis is based. The first approach to resolving this issue is to omit all highly co-linear determining variables from the benchmark Davidson and Tippett (2012) model. When this is done the empirical results strongly support the argument that the relationship between the market value of equity and its determining variables is non-linear, particularly in the case of low-efficiency and high-efficiency sub-sample firms where the non-linear terms contribute significantly to the overall market value of equity. However, for steady-state efficiency firms, which are expected to continue operating under their existing investment opportunity sets into the foreseeable future, there is an approximately linear relationship between the market value of equity and its determining variables. In this case, the non-linear terms contain negligible incremental explanatory power in relation to the overall market value of equity.

The trade-off of omitting variables in order to resolve the co-linearity issue means that our revised regression procedures will be potentially afflicted by an omitted variables problem. It is because of this that the second methodology - Principal Component Analysis (PCA) - is applied to the data on which our empirical analysis is based. The results obtained from PCA show that the non-linear terms substantially increase the explanatory power of the equity valuation model when it is applied to the pooled sample data, the low-efficiency sample data and the high-efficiency sample data. There is, however, a downside to the application of PCA in that it can often be difficult to interpret what the principal components actually represent. Our empirical analysis also shows that for low-efficiency firms the explanatory power of both the linear and non-linear equity valuation models is very low. Our conclusion is that this occurs because the market value of equity for low-efficiency firms listed on the SSE is mainly determined by information other than book value and earnings. Therefore, equity valuation models which encapsulate only traditional accounting information as explanatory variables cannot provide a

satisfactory description of the way that the market value of equity for low-efficiency firms listed on the SSE is determined.

6.2 Contribution, Limitations of the Study and Future Research

6.2.1 Contribution

This dissertation contributes to the accounting-based capital markets literature in three significant aspects. Its first contribution stems from the fact that it provides the first empirical evidence on the impact that earnings momentum and earnings acceleration can have on the market value of equity; in particular, for firms listed on the SSE. Here, my empirical analysis is compatible with the hypothesis that earnings momentum does have an impact on the equity values of firms with moderate operational efficiency. This in turn implies that the investment opportunity sets of such firms must be defined in terms of a higher order system of stochastic differential equations.

A second contribution of my dissertation is that it contributes to our understanding of the application of real option analysis in equity valuation by summarising the strengths and weaknesses of the three most prominent non-linear equity valuation models in the extant literature; namely, the Ashton et al. (2003), Zhang (2000) and Yee (2000) equity valuation models.

Third, although a growing body of empirical evidence now shows that a convex and highly non-linear relationship appears to exist between equity prices and the summary measures which appear in corporate financial statements, all previous empirical studies which test the non-linearity hypothesis are based on piece-wise linear approximations of the relationship between the market value of equity and its determining variables. This contrasts with the empirical analysis summarised in this dissertation for firms listed on the SSE which is based on a power series expansion of the Ashton et al. (2003) non-linear equity valuation model as developed by Davidson and Tippett (2012). The empirical analysis based on the Davidson and Tippett (2012) power series expansion shows that whilst there is a complementary relationship between the valuation coefficients associated with a

firm's earnings and the book value of its equity, it also highlights the very significant impact which the real options generally available to firms can have on the overall market value of a firm's equity.

6.2.2 Limitation of Methodology and Theoretical Modelling

There are a number of limitations associated with the methodology and the theoretical modelling summarised in this dissertation. However, most of these are not unique to this particular study.

The first limitation regards the way in which earnings momentum and earnings acceleration are measured. As is well known from classical mechanics in physics, momentum is normally expressed in terms of the first derivative of a moving object. This contrasts with the empirical analysis summarised in this dissertation which is based on annual data and this in turn means that earnings momentum has had to be defined in terms of the first difference in the earnings variable as follows:

$$x'(t) = \frac{\Delta x(t)}{\Delta t} + O[(\Delta t)^2] = \frac{x(t) - x(t - \Delta t)}{\Delta t} + O[(\Delta t)^2]$$

Similarly, acceleration is normally expressed in terms of the second derivative. However, since our empirical analysis is based on annual data, earnings acceleration has had to be approximated by taking the second difference in the earnings variable as follows:

$$x''(t) = \frac{\Delta x^2(t)}{(\Delta t)^2} + O[(\Delta t)^2] = \frac{x(t) - 2x(t - \Delta t) + x(t - 2\Delta t)}{(\Delta t)^2} + O[(\Delta t)^2]$$

Thus, because our measures of earnings momentum and earnings acceleration are based on first and second differences respectively it means that all higher terms, $O[(\Delta t)^2]$, in the expressions for earnings momentum and earnings acceleration have had to be ignored. This in turn will mean that our empirical analysis of the effects that earnings momentum and earnings acceleration have on equity values will be potentially afflicted by an errors-in-variables problem. Under standard scenarios this will mean that the valuation coefficients associated with

earnings momentum and earnings acceleration will be biased towards zero (Greene, 2012). Hence, there is a strong possibility that our empirical analysis will have under-estimated the effects that earnings momentum and earnings acceleration have on the market prices of equity stocks listed on the SSE.

The second limitation relates to the deflation procedures invoked in my empirical analysis. As discussed in Chapter 4, empirical analysis in this area is usually conducted by deflating all variables by the book value of equity or the book value of total assets in order to address problems of size and heteroskedasticity. It is well-known, however, that when deflated variables are used in regression analysis it leads to a form of spurious correlation which results in biased and inconsistent parameter estimates as well as inflated t and R^2 statistics. In the empirical analysis this dissertation seeks to address the heteroskedasticity issue by employing the number of shares on issue as a deflating variable. The variance of the number of shares on issue is relatively small when compared to the variance of the book value of equity or the variance of the book value of total assets and Davidson and Tippett (2012, p. 245-249) show that reducing the variance of a deflating variable alleviates the spurious correlation effects that arise with the deflation procedure.

Another limitation of the empirical analysis summarised in this dissertation is the inability to incorporate the other information variable into the empirical analysis. Here, it has been previously noted (as in Chapter 2) how the Ohlson (1995) equity valuation model shows that the market value of equity is a linear function of the current book value, the current abnormal earnings and current value of the information variable. Moreover, Ashton et al. (2003) and Davidson and Tippett (2012) develop the Ohlson (1995) model so as to incorporate real option value into the equity valuation process. Thus, in all three models the other information variable is a crucial determinant of equity values. However, empirical tests in this dissertation are all based on models that exclude the information variable. Excluding the information variable may lead to reduced explanatory power - as in the case of the low-efficiency subsample analysed in the previous two chapters of this dissertation. Unfortunately, there is now a long line of literature which shows that it is extremely difficult to find an appropriate proxy for the information

variable with the properties represented in the Ohlson (1995) and Ashton et al. (2003) models (Dechow et al., 1999; Myers, 1999; Collins et al., 1999; Morel, 2003).

The fourth limitation relates to the fact that firms release their annual financial statement at different dates. In this dissertation, it is assumed that the closing share prices on 30 April fully reflect the market's reaction to the assimilated information contained in the financial reports covering the fiscal year ending 31 December of the previous year. However, empirical studies have shown that SSE stock prices are more volatile than stock prices in more mature capital markets. For example, Jarrett and Sun (2012, p. 135) observe that between 1991 and 2009, the variance in the rate of return of the Shanghai Stock Composite Index is almost as eight times the variance in the rate of return of New York Stock Indices. This suggests that the uncertainty in the SSE is much greater than it is for the New York stock market. Given the high volatilities of share prices on the SSE, it is arguable whether the closing share price on 30 April can provide an accurate reflection of the valuation implications of the information summarised in the financial statements of SSE listed firms.

The fifth and final limitation relates to the interpretation given to the coefficients associated with the higher order terms in the polynomial non-linear equity valuation model. In dealing with the co-linearity problem, all empirical tests in this dissertation are based on centred data. However, the issue of interpretation of the coefficients associated with mean-adjusted higher order terms needs to be further explored. For example, the coefficient associated with the centred $b^2(t)x(t)$ in the non-linear regressions is denoted as β_7 (as in equation (5.7) of Chapter 5). As the centred $b^2(t)x(t)$ equals $(b(t) - \overline{b(t)})^2(x(t) - \overline{x(t)})$, where $\overline{b(t)}$ is defined as the mean of book value and $\overline{x(t)}$ is defined as the mean of earnings, it can be shown that:

$$\begin{aligned} \beta_7 (b(t) - \overline{b(t)})^2(x(t) - \overline{x(t)}) &= \beta_7 b^2(t)x(t) + \beta_7 \overline{b^2(t)}x(t) - 2\beta_7 \overline{b(t)}(b(t)x(t)) - \beta_7 \\ &\overline{x(t)}b^2 + 2\beta_7 \overline{b(t)x(t)}(b(t)) - \beta_7 \overline{b^2(t)}\overline{x(t)} \end{aligned}$$

Here it will be recalled that in the non-linear regressions, the coefficients associated with centred $b(t)x(t)$ is denoted as β_4 (again as in equation (5.7) of Chapter 5). However, β_4 cannot capture the real relationship between the term of $b(t)x(t)$ and the market value of equity, as, for example, $-2\beta_7 \overline{b(t)}$ in the equation above will also be a component of the real coefficient that is associated with $b(t)x(t)$. This in turn means that there is a challenge in interpreting the coefficients correctly. Nevertheless, as demonstrated in earlier chapters of this dissertation the significant incremental explanatory power associated with the non-linear terms shows that the inclusion of non-linear terms in equity valuation modeling makes a robust contribution to our further understandings in this important area.

6.2.3 Future Research

There are three areas where the work summarised in this dissertation may be extended and further developed.

First, for steady-state firms our empirical analysis shows that there appears to be an approximately linear relationship between equity values and their determining variables. Moreover, since earnings momentum carries a statistically significant valuation coefficient for our steady-state (that is, moderate) efficiency sub-sample of firms it appears as though the investment opportunity set for these firms will take the form of a second order vector system of stochastic differential equations. However, in the empirical work on which this dissertation is based the investment opportunity set is confined to the traditional accounting variables (that is, the book value of equity and earnings). In future, the Ohlson (1995) “other information” variable can be added to the equity valuation process, and then the momentum and acceleration of both the traditional accounting variables and the Ohlson (1995) “other information” variable can be tested to ascertain whether they exhibit a significant impact on the market value of equity for firms in the steady-state efficiency classification.

Second, by incorporating earnings momentum, earnings acceleration, the information variable and the momentum and acceleration of the information variable into the Davidson and Tippett (2012) non-linear equity valuation power series expansion, a more complete real options based model of equity values can be developed and would be expected to increase its explanatory power to the contemporaneous market value of equity.

Third, the non-linear models applied in this dissertation are afflicted by issues of co-linearity in the independent variables. Here, Ridge regression procedures, nonparametric models and artificial neural network models have the potential to resolve this co-linearity issue.

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