APPLICATION OF THE OPTION PRICING MODEL TO ESTIMATE EXPECTED STOCK RETURNS

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ABSTRACT

APPLICATION OF THE OPTION PRICING MODEL TO ESTIMATE EXPECTED STOCK RETURNS

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This thesis refines and tests an option-based methodology for estimating the expected rate of return on firms' equity, being an approach proposed by Hsia (1991). Hsia's approach is based on an option-theoretic model of the firm, as proposed by Merton (1974) and others. Tests of the Hsia approach are thus joint tests of the Merton model and of the Hsia approach. The Merton model is successfully fitted in its basic form by solving for firm asset volatility and, consistent with prior studies, the implied volatility for firms' assets is found, on average, to be higher than that expected from examining historical equity volatility. The Hsia-based expected excess returns on equity are then estimated and tested in regressions against realised excess stock returns. The Hsia-based expected excess returns are found to be only weakly, positively associated with realised excess returns, and not of statistical significance. When the sample is split in half on the basis of various option-like characteristics (such as higher gearing), the Hsia approach is found to work better for the more option-like sub-sample. This research thus provides some tentative support for the Hsia approach, but does not provide a clear conclusion about its ability to explain the variation in realised excess stock returns. It also provides some ideas and possible directions for further research into applying the Hsia approach.

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Any errors in this thesis are solely the author's responsibility.

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GLOSSARY

A	aggregate annual debt service charges of the firm
B	value of the firm's debt
CAPM	Capital Asset Pricing Model
CBOE	Chicago Board Options Exchange
CBOT	Chicago Board of Trade Options Exchange
d	Merton "quasi" debt-to-firm ratio
D	debt servicing as a percentage of the value of the firm's assets
FRB	US Federal Reserve Board
i	yield on the firm's debt
k_B	expected rate of return on the firm's debt
k_S	expected rate of return on the firm's equity
k_V	expected rate of return on the firm's assets
m	borrowing margin
μ	instantaneous rate of return on the firm's assets
MLHYM	Merrill Lynch High Yield Master II corporate bond index
MM	Modigliani and Miller
N(.)	cumulative probability of the standard normal distribution
OPM	Option Pricing Model
r	risk-free rate of interest
σ_S	standard deviation of rates of return on the firm's equity
σ_V	standard deviation of rates of return on the firm's assets
S	value of the firm's equity
T	time to maturity
V	value of the firm's assets
X	face value of the firm's debt, at maturity

Chapter 1

1 INTRODUCTION

1.1 Background

The purpose of this thesis is to refine and test an option-based methodology for estimating the expected rate of return on firms' equity, being an approach proposed by Hsia (1991). Estimation of the expected rate of return from investing in a firm's equity securities (i.e. shares or stock) is a key issue in the study of corporate finance and investment management, both from an academic perspective and from a practitioners' perspective. Sharpe's (1964) Capital Asset Pricing Model (CAPM) had for many years been widely accepted, in academia and in practice, as a reasonable basis for estimating the expected rate of return for a stock, or a portfolio of stocks. The CAPM is a relatively simple and intuitively appealing model, resulting from rigorous theoretical foundations.

However, in recent years criticism of the CAPM has increased to the point where it is no longer as accepted as a sound model within the academic community. The turning point is, perhaps, Fama and French's 1992 paper. In that paper, and in (1993) and subsequent papers, Fama and French show that, once a firm's relative size and book-to-market value are allowed for, a firm's equity beta (as per the CAPM) has little ability to explain the variation in realised returns. Fama and French's three factor model is becoming more widely viewed as a better model than the CAPM in explaining the variation in historical stock returns. Debate continues as to the economic meaning of the additional two factors (size and book-to-market).

The last three decades have also seen an explosion in the use of financial derivatives. The pioneering Black-Scholes option pricing model (OPM) has now also become widely accepted in academia and in practice. This model has provided the foundation for many developments in the area of derivatives pricing.

Additionally, Black and Scholes (1973) and Merton (1973) recognise that the equity in a firm can be viewed as an option on the firm's assets, with the exercise price being the firm's outstanding debt. Merton (1974) further develops this concept, to explain the risk structure of interest rates for corporate debt. This option-theoretic view of a firm has come to be known as the Merton model or the structural model of the firm. The Merton model provides the foundation for developing an option-based approach to estimating the firm's cost of capital.

Galai and Masulis (1976) combine the Merton model with Sharpe's CAPM. By doing so they derive an expression for the instantaneous expected rate of return on equity. Hsia (1981) also demonstrates the coherence between the OPM and the CAPM and derives resulting expressions for the expected rate of return on a firm's equity (as per Galai and Masulis) and on its debt. This theoretical approach to estimating the expected rate of return on a firm's equity is also espoused in finance texts, such as Copeland and Weston (1992).

Hsia (1991) further develops this concept by proposing a method for practically applying the OPM to estimate a firm's cost of capital (henceforth referred to as the Hsia approach). The resulting model only requires the input of readily observable current parameters to estimate, ex ante, the expected rate of return on a firm's equity.

An interesting question is whether or not the Hsia approach produces useful estimates of expected stock returns. Do Hsia-based estimates of expected

returns have greater explanatory power than CAPM betas? Do Hsia-based expected returns have any explanatory power compared to the Fama-French three factor model?

1.2 Research Aim

The research aim of this thesis is to test whether or not application of the Hsia approach, which is based on the Merton option-theoretic model of the firm, can provide "meaningful" ex ante estimates of firms' expected rates of return on equity. The benchmarks for "meaningfulness" will be whether or not Hsia's approach can explain the variation in realised equity returns better than other widely used models such as the CAPM and the Fama-French three factor model.

1.3 Objectives

To achieve this aim the research has the following objectives:

1. To review the literature to see how the Merton model has evolved and has been tested in various settings.
2. To ascertain the extent, if any, to which the Hsia approach has been empirically tested.
3. Based on the literature review consider modifying the Hsia approach to improve the prospects of it working in an empirical setting. In particular to review the methods for estimating the various model inputs.
4. To test the Hsia approach (as modified per 3. above) on a large sample of US firms, to ascertain if expected rates of return on equity estimated ex ante using the Hsia approach have any ability to explain the ex post variation in realised returns.

5. To compare the statistical significance of the Hsia approach versus ex ante CAPM beta estimates in explaining the ex post variation in realised returns.
6. To compare the statistical significance of the Hsia approach versus ex ante estimates of the three Fama-French factors in explaining the ex post variation in realised returns.

1.4 Research Undertaken

In this thesis the underlying option-theoretic model of the firm, the Merton model, and the Hsia approach for estimating the firm's cost of equity, are specified relative to the firm's borrowing margin. Firms' borrowing margins are then estimated by reference to their credit rating and the credit spread implicit in the yield on corporate bond indexes of the same credit rating. The Merton model is then fitted, largely using the approach suggested by Hsia (1991), and Hsia-based expected excess returns are then estimated. Tests of the Hsia approach are thus joint tests of the Merton model and of the Hsia approach.

The Merton model is successfully fitted in its basic form by solving for firm asset volatility and, consistent with prior studies, the implied volatility for firms' assets is found, on average, to be higher than that expected from examining historical equity volatility. There is also evidence that this problem, of needing to "over estimate" volatility, is more pronounced the less "option-like" the firm is, e.g. for firms with low leverage.

Errors in estimating firms' true asset volatility will affect the ability of the Hsia approach to explain the variation in realised stock returns. It is postulated that there may be a systematic bias introduced to the estimation of the Hsia-based expected excess returns as a result of larger "over estimates" of firm asset volatility being required the less option-like a firm is.

1.5 Research Findings

Month-by-month regression tests are done, with monthly realised excess stock returns as the dependent variable. Across the full sample of 46,553 firm-months the Hsia-based expected excess returns are found to be only weakly, positively associated with realised excess returns, and not of statistical significance at the 0.05 level. For the sample firms, over the sample period, the CAPM is tested and beta is not found to be statistically significant at the 0.05 level.

Size and book-to-market variables have somewhat more explanatory power than the Hsia approach or beta, when both are present in the regression model, but are still not of statistical significance at the 0.05 level. Moreover, upon inclusion of beta and/or book-to-market in the regression model the sign of the size coefficient is positive, which is contrary to the findings of Fama and French (1992). Further, unlike Fama and French (1992), neither size nor book-to-market is statistically significant (at the 0.05 level) in any of the models tested. These differences from Fama and French's findings are likely to reflect the shorter time period used in this study and the different (more restrictive) criteria for selecting firms to be included in the analysis.

When the sample is split in half on the basis of various option-like characteristics (such as higher gearing), the more option-like sub-sample is found to have a greater positive loading and higher t-statistic for the Hsia-based expected excess return variable. However, none of the slope coefficients is statistically significant at the 0.05 level. Moreover, the improved statistical power of the relationship is found to be driven by a relatively small number of extreme return observations.

This research thus provides some tentative support for the Hsia approach, but does not provide a clear conclusion about its ability to explain the

variation in realised excess stock returns. It also provides some ideas and possible directions for further research into applying the Hsia approach.

1.6 Structure of Thesis

The remainder of this thesis is set out as follows. Chapter 2 reviews the relevant literature on asset pricing theory, in particular the Merton model and extensions of that model. Chapter 3 reviews the literature on empirical tests of the OPM, the Merton model and the Hsia approach. Chapter 4 discusses the data sources, issues arising with the data and the methodology used to implement the Hsia approach. Chapter 5 presents, analyses and discusses the results from fitting the Merton model and then applying the Hsia approach. Chapter 6 concludes.

Chapter 2

2 LITERATURE REVIEW – THEORETICAL FRAMEWORK

2.1 The Option-Theoretic View of the Firm

Before reviewing the development of the Hsia approach, it is useful to first review the development of the option-theoretic view of the firm, upon which the former is founded.

Black and Scholes (1973) derive a formula for the valuation of a call option that, they state, also provides a way to view the position of stockholders' claim over the assets of their firm:

> *"In effect, the bond holders own the company's assets, but they have given options to the stockholders to buy the assets back."* (Black and Scholes, 1973, p.649)

The Black-Scholes OPM, when used as an equity valuation model, is defined as[1]:

$$S = VN(d_1) - Xe^{-rT}N(d_2) \qquad (1)$$

where:

- S is the value of the firm's equity
- V is the value of the firm, being the sum of the value of its debt and equity (i.e. the value of the firm's underlying assets)

[1] The Black-Scholes notation, and that of other literature reviewed, has been standardised on a common basis for the purpose of this thesis.

X is the face value of the firm's debt, which is assumed to be a single zero-coupon bond, at maturity (i.e. the "exercise price")

T is the time to maturity (the expiry date) of the firm's debt

$$d_1 = \left(\left[\ln\left(V/X\right) + rT\right]/\sigma_V\sqrt{T}\right) + (1/2)\left(\sigma_V\sqrt{T}\right) \quad (2)$$

$$d_2 = d_1 - \sigma_V\sqrt{T} \quad (3)$$

$N(.)$ is the cumulative probability of the standard normal distribution with d_1 or d_2 as the upper limit

r is the instantaneous risk-free rate of interest per unit of time

σ_V is the instantaneous standard deviation of rates of return on the firm per unit of time (conventionally expressed in annualised terms).

Key assumptions underlying the Black-Scholes OPM, as applied to the firm's equity, are:

1. The short term rate (i.e. risk-free) of interest is known and is constant through time.
2. The price of the firm's assets follows a random walk in continuous time, hence the distribution of future possible asset values is log normal with constant variance.
3. The firm makes no distributions (i.e. no interest or dividends are paid prior to the exercise date).
4. The "option" is European – it can only be exercised at maturity (i.e. the bondholders cannot force bankruptcy prior to the firm's debt maturing).
5. There are no transactions costs in buying or selling the firm's assets or equity.
6. It is possible to borrow at the short term rate (i.e. risk-free) of interest.
7. There are no penalties to short selling.

8. The firm has only one class of zero coupon debt, maturing on the "exercise date".
9. The absolute priority rule applies under bankruptcy.

Black and Scholes acknowledge that the assumption that the firm has only one class of zero coupon, non-callable, non-convertible debt is abstract and that the presence of complexities such as the firm having more than one class of debt, interest coupon payments, dividend payments, callable bonds and convertible bonds is not handled by their valuation formula.

Merton (1973) also recognises that the equity in a firm can be viewed as an option on the firm's assets, with the exercise price being the firm's outstanding debt. Merton (1974) states that the value of a particular issue of corporate debt depends essentially on:

1. The required rate of return on riskless (in terms of default) debt;
2. The various provisions and restrictions contained in the debt contract; and
3. The probability that the firm will default.

Using the option-theoretic view of a firm Merton derives expressions for the valuation of "risky" corporate debt, which are consistent with the Black-Scholes OPM. Merton goes on to present a comparative statics analysis of the risk structure of interest rates.

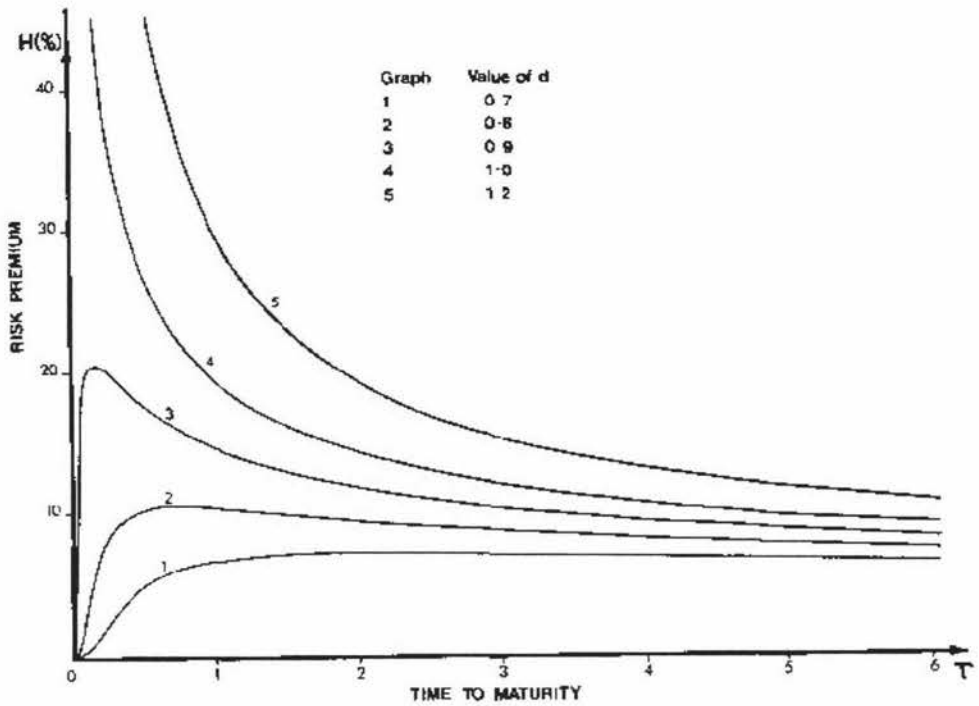
In addition to the Black-Scholes assumptions, other key assumptions made by Merton are that:

1. The Modigliani-Miller (1958) theorem holds, that is the value of the firm is invariant to its capital structure.
2. The term structure of interest rates is constant.

The Merton model makes some predictions about the behaviour of firms' borrowing margins or credit spreads (as measured over a risk free government security), as a function of debt maturity and firm leverage. For moderately leveraged firms the Merton model of risky corporate debt predicts a "humped" shaped credit spread curve. As the maturity of the firm's debt draws closer, and providing the face value of debt is less than the value of the firm's assets, the credit spread on the firm's debt will approach zero. In the short to medium term credit spreads are predicted to rise, while over longer time horizons the model then predicts declining credit spreads. For highly leveraged firms the model predicts a downward sloping term structure of credit spreads, while for lowly leveraged firms an upward slope is predicted.

Pitts and Selby (1983) provide a plot [their Figure 1, p. 1313] of theoretical credit spreads by debt maturity, using the Merton model, with a range of curves using different "quasi" debt-to-firm value ratios (d, where $d = Xe^{-rT}/V$), shown as Figure 1 below.

Figure 1
Credit Spreads by Debt Maturity



As discussed by Helwege and Turner (1999) the intuition behind these different term structures of credit spreads is that corporate bond values reflect the probability of default, which in turn depends on firm value:

1. For bonds of the highest quality the probability of default is very small at issuance, so there is minimal prospect of the bond quality improving no matter how much the value of the firm rises. However, there is a much greater chance that credit quality will decline over time – hence the term structure of credit spreads is upward sloping for such firms (e.g. series 1 above).
2. For bonds of the lowest quality (i.e. very risky) at issuance there is a much greater chance of bond quality improving over time (i.e. the firm value

could rise substantially) – hence the credit spread curve is downward sloping (e.g. series 4 and 5 above).

3. For bonds in between the two cases above, in the short term the possibility of a decline in credit quality dominates, while in the longer term the upside potential from an increase in firm value dominates – hence a humped shaped credit spread curve is predicted by the Merton model (e.g. series 2 and 3 above).

These insights are not directly relevant to Hsia's (1991) approach, but are of importance when considering empirical tests of the underlying Merton model.

2.2 Extensions of the Option-Theoretic Framework

The Merton model has been extended to allow for a number of more realistic assumptions, including:

1. The effects of bond indenture provisions, including the possibility of early default (Black and Cox, 1976);
2. Convertible securities (Ingersoll, 1977);
3. Coupon bonds (Geske, 1977);
4. The possibility of early default, a stochastic default boundary and interest rate risk (Neilsen, Saá-Requejo and Santa-Clara, 1993);
5. Cash flow triggered default and interest rate risk (Kim, Ramaswamy and Sundaresan, 1993);
6. Stochastic interest rates (Shimko, Tejima and van Deventer, 1993);
7. Bankruptcy costs, corporate taxes, exogenously determined bankruptcy, cash payouts by the firm and violation of absolute priority under bankruptcy (Leland, 1994);
8. The possibility of early default, interest rate risk and violation of absolute priority under bankruptcy (Longstaff and Schwartz, 1995);

9. A game theoretic approach to debt contracting and bankruptcy (Anderson and Sundaresan, 1996);
10. Endogenously determined bankruptcy (Leland and Toft, 1996);
11. Strategic debt servicing by equity holders, who can make "take-it-or-leave-it" offers to bondholders (Mella-Barral and Perraudin, 1997);
12. The possibility of early default, interest rate risk and violation of absolute priority under bankruptcy (Briys and de Varenne, 1997);
13. Non-continuous disclosure and imperfect accounting information (Duffie and Lando, 2001);
14. The possibility of early default, a jump-diffusion asset price process and violation of absolute priority under bankruptcy (Zhou, 2001).

The primary focus of the above line of research has been the pricing of risky corporate bonds (i.e. credit risk), as opposed to the pricing of equity or estimating the expected rate of return on equity.

In parallel with the development of the Merton model to price credit risk, an alternative model, the "reduced form model", has been developed. This approach does not explicitly model the value of the firm; rather default is modelled as an exogenous random process. Such models can be fitted to observed credit spreads and the term structure of interest rates (using arbitrage free assumptions), to provide a basis for pricing credit risk. Since this approach is not directly relevant to the application of Hsia's approach and the Merton model, it is not considered further in this study. Overview articles that compare the Merton and reduced form models include Nandi (1998) and Kao (2000).

2.3 Criticism of the Merton Model

A feature of the Merton model is that as the time to maturity approaches zero (and providing the current value of the firm's assets exceeds the present value of its debt obligations) the instantaneous probability of default approaches zero and hence the firm's credit spread is also predicted to approach zero. This prediction from the model is not reflected in credit spreads observed in practice, but is a logical consequence of the model's assumption that the value of the firm's assets follows a continuous time diffusion process. Under such a process, and providing the firm is not already in default, the value of the firm's assets can only move by a small amount over a small time period. Hence as that time period becomes small enough, it becomes virtually impossible for the value of the firm's assets to fall below the level where default is triggered. A number of the extensions to the Merton model have sought to address this particular shortcoming of the basic model.

Several authors note other weaknesses of the Merton model, which have, generally, not been addressed by the extensions to the model noted above. For example, Jarrow and Turnbull (2000) note that there are at least four practical difficulties to implementing the model:

1. It is rarely possible to know the market value of the firm's assets (the argument here is that the market value of the firm's assets cannot be simply measured as the sum of the market values of debt and equity since the market value of all the firm's liabilities, including unrecorded liabilities, is unlikely to be observable).
2. Given that the true market value of the firm's assets may not be known, it is therefore not possible to measure the return volatility of the firm's assets.

3. Most firms have complex liability structures. This causes significant computational difficulties.
4. The model only allows default to occur at specific times (in the basic Merton model this is upon maturity of the firm's single class of debt, some extensions of the model allow default to occur at interest coupon payment dates). In the real world default may occur at any time.

Garbade (1999) argues that a firm's management has discretion over a number of "options", such as early redemption of debt and dividend policy, which are usually ignored under the Merton model. Such errors and omissions could lead to the Merton model overstating the value of senior debt securities and understating the value of equity.

2.4 Using the Option Pricing Model to Estimate the Cost of Equity

Galai and Masulis (1975) [their equation (13), p.60] demonstrate the relationship between the Black-Scholes option pricing model (as applied to the firm), the expected rate of return on the firm's assets (k_V) and the expected rate of return on the firm's equity (k_S) with the following equation:

$$k_S = r + N(d_1)[k_V - r]\frac{V}{S} \tag{4}$$

Hsia (1981) demonstrates the coherence between the CAPM, Modigliani-Miller's (MM) Proposition II without taxes[2] (Modigliani and Miller, 1958) and the Black-Scholes option pricing model. In addition to deriving equation (4), above, for the cost of equity, Hsia (1981) also derives the following equation for the cost of debt (k_B):

[2] MM Proposition II without taxes means that firm value is invariant to financial leverage.

$$k_B = r + N(-d_1)[k_V - r]\frac{V}{B} \tag{5}$$

Hsia (1991) went on to derive a formula for the cost of equity (k_S) that did not require knowledge of k_V. A derivation of this is shown below.

In a MM world without taxes:

$$k_V = \frac{B}{V}k_B + \frac{S}{V}k_S \tag{6}$$

Substitute (6) into (4) to obtain:

$$k_S = r + N(d_1)\left[\left(\frac{B}{V}k_B + \frac{S}{V}k_S\right) - r\right]\frac{V}{S} \tag{7}$$

Rearranging:

$$k_S = r + N(d_1)\frac{B}{S}k_B + N(d_1)k_S - N(d_1)\frac{V}{S}r \tag{8}$$

Gives:

$$k_S N(-d_1) = r + N(d_1)\frac{B}{S}k_B - N(d_1)\frac{V}{S}r \tag{9}$$

Simplifies to:

$$k_S N(-d_1) = rN(-d_1) + (k_B - r)\frac{B}{S}N(d_1) \tag{10}$$

And finally:

$$k_S = r + (k_B - r)\frac{B}{S}\frac{N(d_1)}{N(-d_1)} \tag{11}$$

Which is Hsia's (1991) equation [his equation (11b) , p.285] for estimating a firm's cost of equity using the Black-Scholes option pricing model. This theoretical approach to estimating the expected rate of return on a firm's

equity is also espoused in some finance texts, such as Copeland and Weston (1992).

Using equation (11), the parameters required to estimate k_S are thus:

- S the value of the firm's equity
- V the value of the firm
- X the face value of the firm's debt at maturity
- T the time to maturity of the firm's debt
- r the instantaneous risk-free rate of interest per unit of time
- σ_V the instantaneous standard deviation of rates of return on the firm per unit of time
- k_B the firm's cost of debt.

Hsia (1991) derives methods for estimating each of these parameters as follows:

- S is taken as the observed market value of the firm's equity
- V equals the sum of S and the present (i.e. market) value of the firm's debt (B)
- X equals Be^{iT}, where e is the exponential function and i is the continuously compounded yield on the firm's debt (i.e. i is the firm's cost of debt or k_B)
- T equals $1/i$; based on the assumption that the term to maturity of a zero coupon bond is equal to its duration
- r is taken as the observed risk-free rate of interest in the market

σ_V is solved for endogenously, using all of the above parameters and the Black-Scholes OPM

k_B can be measured as the firm's aggregate annual debt service charges (A) divided by B.

Thus under Hsia's approach the only inputs required to estimate the firm's cost of equity are: - the market values of the firm's equity (S) and debt (B), the firm's annual debt servicing costs (A) and the risk-free rate of return (r).

2.4.1 Rearranging the Model

From equation (11) the risk premium, or excess return, on the firm's equity $(k_S - r)$ can be expressed as multiple of the firm's borrowing margin $([k_B - r] \text{ or } m)$ as follows:

$$(k_S - r) = m\frac{B}{S}\frac{N(d_1)}{N(-d_1)} \tag{12}$$

It is apparent from equation (12) that the estimation of the excess return on equity under this model will be highly sensitive to the estimation of the firm's borrowing margin, m.

Equation (12), for the excess return on the firm's equity, can be solved so that the risk-free rate is not required as an input to the calculation of the right hand side of the equation. By introducing the term m and using Hsia' (1991) definition of X, equation (1) can be re-written[3] as:

$$S = VN(d_1) - Be^{mT}N(d_2) \tag{13}$$

where:

[3] This formulation of the Merton model is proposed by Cooper and Davydenko (2001).

$$d_1 = \left(\left[\ln\left(V/B\right) - mT\right]/\sigma_V\sqrt{T}\right) + (1/2)\left(\sigma_V\sqrt{T}\right) \quad (14)$$

$$d_2 = d_1 - \sigma_V\sqrt{T} \quad (15)$$

This formulation of the model is useful to be able to estimate the predicted excess return on equity without specifically requiring a risk-free rate input (although an estimate of the absolute cost of debt $\left(k_B \text{ or } i\right)$ is still required to estimate T). This obviates the need to determine which maturity of risk free instrument should be used to fit the Merton model and then apply the Hsia approach (e.g. 30 day T-bill or long term Treasury bond?).

Chapter 3

3 LITERATURE REVIEW – EMPIRICAL TESTS

3.1 Empirical Tests of the Black-Scholes Option Pricing Model

Since the Merton model/Hsia approach is based on the Black-Scholes OPM formula, it is useful to briefly review some of the empirical tests on the performance of the OPM.

3.1.1 Black and Scholes (1972)

The Black-Scholes OPM has been subject to extensive empirical testing. One of the earliest tests is by Black and Scholes (1972) themselves. Using market data for the period 1966 through 1969 for "over the counter" options on exchange traded stocks, they construct notional risk neutral hedge portfolios, consisting of a long position in "undervalued" options and a short position in the related stock (or vice versa for "overvalued" options). Whether or not options are "undervalued" or "overvalued" is determined by comparing Black-Scholes model prices (using historical stock volatility) with market prices. They then examine the profitability (i.e. excess returns) of a trading strategy based on these "undervalued" and "overvalued" portfolios. They find that their OPM tends to overprice options on high variance stocks and underprice options on low variance stocks. However, once transactions costs are allowed for the implied profits from a trading strategy based on this phenomenon disappear.

3.1.2 Galai (1977)

Galai (1977) tests the Black-Scholes model using data on exchange traded options, using the hedge portfolio approach of Black and Scholes (1972) and

also examines the profitability of "spreading" strategies. The data is for options traded on the Chicago Board Options Exchange (CBOE) for the period 26 April 1973 through 30 November 1973. To add a degree of realism to applying his trading rules, for some tests, Galai assumes execution occurs at the next trade after the one that provided the price information used for the trading decision. Similar to Black and Scholes (1972), Galai finds that trading strategies based on the Black-Scholes OPM produce small positive excess returns before transaction costs. After allowing for transaction costs these profits disappear, leading Galai to conclude that a non-member of the CBOE would not be able to consistently achieve excess returns.

3.1.3 MacBeth and Merville (1979)

MacBeth and Merville (1979) analyse data for options, in respect of six stocks, traded on the Chicago Board of Trade Options Exchange (CBOT) over the period 31 December 1975 through 31 December 1976. For each option, on each trading day, they solve the Black-Scholes OPM for the implied stock price volatility, given the option's price and other market data. They find that for some deep in-the-money options with less that ninety days to expiration, a plausible implied volatility cannot be calculated. For the remainder of their sample they find that the implied volatilities vary from day to day and that implied volatility (for the same stock on the same day) declines as exercise price increases. They also find that implied volatility varies with time to expiration, according to whether the option is in-the-money or out-of-the-money.

MacBeth and Merville conclude that the Black-Scholes OPM underprices in-the-money options and overprices out-of-the-money options, this "mispricing" tends to increase the more in (or out) of-the-money the option is and the greater the time to expiration (with the exception of out-of-the-money options with less than ninety days to expiration). Their results suggest that the Black-Scholes OPM could systematically misprice options that are

deep in-the-money or out-of-the-money, particularly those with longer time until expiration. However, they do not examine whether any potentially profitable trading strategies based on their findings would persist after allowing for transaction costs.

3.1.4 Bhattacharya (1980)

Bhattacharya (1980) notes that prior tests of the Black-Scholes OPM have been joint tests of the model and of market efficiency (and are also hypotheses about the measurement of model inputs and outputs). To get around this problem they test the Black-Scholes OPM using notional options that are priced in accordance with the model (as opposed to market prices), and then test for excess returns by constructing hedge portfolios using these options and their underlying stocks. Bhattacharya finds that the Black-Scholes OPM overvalues all at-the-money options with five days or less to expiration. While the model generally undervalues near-the-money options, on either side. However, other than for one day to maturity at-the-money options, excess hedge returns are not statistically and operationally significant.

3.1.5 Rubinstein (1985)

Rubinstein (1985) examines time stamped trading records of all reported trades and quotes on the 30 most active CBOE option classes from 23 August 1976 through 31 August 1978. By using time stamped records he is able to ensure option prices can be matched with contemporaneous stock prices. He solves the Black-Scholes OPM for the implied volatility of pairs of options traded over the same time, over the same stock, but with different expiration dates and/or strike prices. Rubinstein finds strong evidence that out-of-the-money or deep out-of-the-money calls have higher implied volatility the shorter the time to expiration. However, other time to expiration biases and strike price biases, while statistically significant, are not of the same sign throughout the full sample period. No alternative models to the Black-Scholes model are able to account for all of the observed biases.

Rubinstein notes that while some of the biases found are statistically significant, they are not necessarily economically significant.

3.1.6 Mayhew (1995)

Mayhew (1995) reviews the literature on option implied volatility. He notes the mixed results from prior research. While a consensus view had emerged that the Black-Scholes OPM performs reasonably well for at-the-money options with one or two months to expiration, the market does not price all options according to the Black-Scholes formula. The presence of systematic differences in implied volatility across strike prices and across time to expiration, when using the Black-Scholes OPM, has come to be known as the "volatility smile". As Mayhew points out this is actually evidence that the asset return assumptions underlying the Black-Scholes OPM do not hold; i.e. stock prices do not follow a diffusion process with constant variance.

3.1.7 Summary on Empirical Tests of the Black-Scholes Option Pricing Model

The results of early empirical testing of the Black-Scholes OPM are generally supportive of the robustness of the model, particularly once transaction costs are allowed for. More rigorous testing established the presence of pricing biases with respect to strike price and time to expiration. Although the sign and persistence of these biases does not appear to be stable over different time periods and data samples. Rather these biases, or the "volatility smile", suggest that the asset price process underlying the Black-Scholes OPM does not hold in the real world. As a result of this generally held view, more recent developments in the field of option pricing have focussed on alternative return generating processes, including extraction of implied return distributions from the prices of traded options.

Nevertheless, the continued widespread use of the Black-Scholes model suggests that it continues to be a "good enough" model in many circumstances, particularly once trading frictions and transaction costs are

allowed for. The empirical evidence against the economic power of the Black-Scholes OPM is not considered sufficiently strong to reject its suitability for application in a Merton model framework.

It is noted that the results of MacBeth and Merville (1979), suggest that the Merton model may not work well for firms with low levels of debt (i.e. whose equity is a well in-the-money option). The situation of equity being a well out-of-the money option is unlikely to arise since by definition such firms are likely to already be in default.

Mayhew's (1995) observation that the Black-Scholes OPM performs reasonably well for at-the-money options with one or two months to expiration also suggests that the Merton model/Hsia approach may work best for highly geared firms (whose equity is an "at-the-money option"), with a higher cost of debt (which translates into a shorter expiration date under the Hsia approach, albeit unlikely to be as short as one or two months).

3.2 Empirical Tests of the Merton Model

Hsia's approach is based on the Merton model, which has been empirically tested in several settings, in particular the pricing of risky debt (i.e. estimation of credit spreads). Merton based models have also been used to predict credit ratings, credit rating changes, ex-dividend stock price behaviour, market valuation of bankrupt firms and bankruptcy prediction. It is useful to review this empirical work to gain an understanding of the methodological issues arising in applying the Merton model and insight into the potential efficacy of the Hsia approach.

3.2.1 Estimation of Credit Spreads

3.2.1.1 Jones, Mason and Rosenfeld (1984)

Jones, Mason and Rosenfeld (1984) test the Merton model for pricing risky debt (which allows for the risk of default) using, as a benchmark, a "naïve" model which values corporate debt using a risk-free discount rate, plus the effects of call provisions and sinking fund options. The Merton model is extended to allow for sinking fund provisions and for multiple debt issues by the sample firms selected. Sample firms were selected using the following criteria:

1. Simple capital structure (one class of stock, no convertible bonds, small number of debt issues, no preferred stock);
2. Small proportion of private debt to total capital;
3. Small proportion of short term notes payable or capitalised leases to total capital; and
4. All publicly traded debt is rated.

Using these criteria 27 US listed firms were selected for which monthly data is available from January 1975 through January 1981. Detailed bond information is obtained from Moody's and Standard and Poors. Two methods are used to estimate the standard deviation of the value of each firm:

1. Each month the value of each firm is estimated as the sum of the market value of its equity, the market value of its traded debt and the estimated value of its non-traded debt[4]. Logarithmic total returns are calculated, allowing for any cash payouts/payins, and the standard deviation of these is then measured ("Method I").

[4] Estimated assuming the ratio of market value to book value is the same as for the firm's traded debt that month.

2. Method I is run to provide a seed value for σ_V, which is then used in the Merton model to make first pass estimates of V, S and $N(d_1)$ which are implied by the observed total value of marketable claims. Using three months of daily stock return data σ_S is measured for each firm, then using the relationship:

$$\sigma_S = \sigma_V \frac{V}{S} N(d_1) \tag{16}$$

a new estimate of σ_V is made. The Merton model is then rerun using this new estimate of σ_V ("Method II").

Since not all claims on the firms are publicly traded, Jones, Mason and Rosenfeld note that the value of the firm cannot be observed. Accordingly, they use the total value of all traded claims to infer (using the Merton model) the value of the firm. They then solve numerically to price the corporate bonds in their sample[5].

Jones, Mason and Rosenfeld (1984) find that the Merton model, as applied by them, significantly outperforms their "naïve" model in pricing corporate bonds. The performance of the two models is similar for investment grade bonds, but the Merton model performs significantly better for non-investment grade bonds. Within sub-samples of non-investment grade bonds the Merton model tends to perform somewhat better than the "naïve" model for firms/bonds with: - low variance estimates, high financial leverage, long term bonds, junior bonds, low price bonds or bonds with high current yields. Regression tests by Jones, Mason and Rosenfeld on the bond pricing errors using the Merton model suggest that their variance estimates are over-stated, particularly their higher variance estimates.

3.2.1.2 Ogden (1987)

Ogden (1987) tests a Merton-based model on bonds newly issued by firms with simple capital structures. The model allows for coupon and dividend payments, callable debt and sinking fund payments. He tests the model's ability to explain credit ratings and, secondly, its ability to explain the variation in corporate bond yield premiums. The sample firms/bonds had to meet the following criteria:

1. The firms' bonds were issued post-1972 (from when long term US Treasury bond data was available);
2. Only new issue corporate bond data was used (to ensure credit rating information was timely);
3. Each bond must be callable, must have a sinking fund provision, must have a maturity greater than 10 years and must have a market value within $10 (per $100 par) of par value;
4. Common stock return data must be available for the 30 months prior to the month in which the bond was issued;
5. The firm's capital structure must be close to the ideal of the model. The screening criteria for this were:
    a. The bond issue must constitute at least 60% of the firm's long term debt (based on book values);
    b. The total book value of ignored long term debt must be less than 20% of the total book value of equity;
    c. The total book value of non-common equity claims (i.e. preferred stock, warrants etc.) must be less than 10% of the total book value of all equity claims.

[5] It is not clear from the paper, but it assumed that their Method II estimate of σ_V was used for this purpose.

Based on these criteria Ogden's sample comprises 57 bonds issued from 1973 through 1985. 30 months of stock return data is used to estimate σ_S for each firm. Over the same 30 month period S is measured using average market values, while V is measured using the average market values of S plus the average book values of debt. An initial estimate of σ_V is then made based on the relationship:

$$\sigma_S = \sigma_V \frac{V}{S} N(d_1) \tag{17}$$

assuming that $N(d_1)=1$. The Merton-based bond pricing model is then solved to provide a revised estimate of $N(d_1)$, which is then used in the preceding equation to provide a revised estimate of σ_V. This process is repeated until the value of σ_V converges.

Ogden's first analysis is a probit analysis of bond ratings using the two explanatory variables suggested by the Merton model: - firm standard deviation (σ_V) and leverage (B/V). Numerical values are assigned to Standard and Poors (S&P) ratings and the resulting probit analysis shows that the two variables explain 78.6% of the variation in ratings and provide correct rating classifications for 61.4% of the bonds in the sample. Ogden notes that these results compare favourably with previous studies using more variables. The addition of a firm size factor improves these statistics to 85.5% and 63.2% respectively. Ogden notes that this suggests that the Merton model is not robust to changes in scale.

Ogden's second analysis is a regression analysis of observed corporate bond yield premiums (i.e. corporate bond yield less the yield on a fixed maturity Treasury security of similar maturity) against the premiums estimated from his

Merton-based model. The expected intercept and slope coefficients from the regression are 0 and 1, if the model provides unbiased estimates of yield premiums. The actual coefficients from Ogden's sample are 1.042 and 0.925, with an adjusted R^2 of .594. Thus while the model explains nearly 60% of the variation in observed bond yield premiums and the slope coefficient is within one standard deviation of its expected value, the large positive value for the regression intercept means that the mean yield premium predicted by the model is only 57% of the mean observed yield premium.

Ogden then examines the errors from the above analysis, by regressing these against potential explanatory variables: - firm size, whether the bond is investment grade or not, Treasury yield and a term structure variable (the latter two variables to test the reasonableness of the Merton model assumption of non-stochastic interest rates). Ogden finds that the grade of the bond (investment or speculative/"junk") is not significant, while the firm size and interest rate variables are significant – suggesting that the Merton model is mis-specified with regard to its assumptions of firm scale invariance and non-stochastic interest rates.

3.2.1.3 Sarig and Warga (1989)

To alleviate the problems arising from applying the Merton model to price corporate bonds with sinking fund provisions, which are callable and/or with more than one promised payment Sarig and Warga (1989) test the model using only pure discount (i.e. zero coupon) corporate bonds. The data for pure discount corporate bonds is drawn from the period February 1985 through September 1987. Bond prices are screened to include only actual transaction prices as opposed to traders' estimates (i.e. the sample excluded so called "matrix" prices). The data is also filtered to exclude: - bonds for which a rating change occurred in that month, bonds which were priced outside the

boundaries suggested by otherwise identical bonds of different maturity and bonds which were economically callable.

The yield spreads (over zero coupon Treasury securities of the same maturity) are computed for the corporate bonds in the sample, then averaged by credit rating and maturity. These yield spreads are plotted by Sarig and Warga, who find that the term structure of the yield spreads closely resembles the theoretical plot obtained by Merton (1974) and others (assuming that credit ratings are negatively correlated with Merton's measure of leverage). Namely that the term structure of the risk premium is:

1. Upward sloping for high rating bonds;
2. Humped for medium rating bonds; and
3. Downward sloping for low rating bonds.

The small size of Sarig and Warga's sample precluded more formal statistical analysis. They also caveat their analysis for the fact that the firms in their sample had more than one class of debt on issue, while an assumption of the Merton model is that only one pure discount bond is outstanding.

3.2.1.4 Fons (1994)

While Fons (1994) does not directly test the Merton model for pricing risky corporate debt, his examination of the structure of credit spreads provides some support for the empirical predictions of the Merton model. Firstly, Fons constructs theoretical credit spread curves, by credit rating category, using historical default rate and recovery rate data. The curves for all investment grade ratings (Moody's ratings Aaa, Aa and A) and the speculative grade rating Baa all exhibit the upward slope predicted by the Merton model for high quality debt. The credit spread curve for the Ba rating shows the hump shape predicted by the Merton model for firms of intermediate credit

quality, while the curve for the B rating is downward sloping – as predicted by the Merton model for firms of low credit quality.

Secondly, Fons examines the actual credit spreads for over 4,000 rated, straight US corporate bonds as of 30 September 1993. He then fits a linear regression line to the data (i.e. credit spread against maturity) for each credit rating. The credit spread line for Aaa rated bonds did not a have a slope significantly different from zero, while the fitted credit spread lines for the credit ratings Aa, A and Baa all had statistically significant positive slopes. The credit spread line for the Ba rating did not a have a slope significantly different from zero, although visual examination of the data plot suggests that if a non-linear regression had been fitted by Fons, instead of linear, then a hump shaped credit spread curve may have been apparent. The fitted credit spread line for the B rated bonds had a statistically significant negative slope.

In summary, Fons' analysis provides empirical support for the credit spread curve predictions of the Merton model.

3.2.1.5 Wei and Guo (1997)

Wei and Guo (1997) empirically compare the Longstaff and Schwartz (1995) and Merton models for pricing risky debt. Key differences between the models are that the Longstaff and Schwartz model incorporates variables for a stochastic risk-free term structure and an exogenous recovery rate in the event of default, while the Merton model assumes a fixed risk-free rate and uses an endogenous recovery rate in the event of default.

Wei and Guo analyse the credit spread between Eurodollars (i.e. US dollar denominated commercial bank certificates of deposit) and US T-bills, over maturities ranging from seven days to one year. The two models are fitted to weekly credit spread data for the 1992 calendar year. In the case of the Merton model the observed term structure of credit spreads is used to

estimate values for the firm leverage and firm volatility variables by employing a grid search algorithm.

For the period analysed the term structure of credit spreads is found to be "N" shaped – a shape that cannot be produced by either the Longstaff and Schwartz or Merton models. Notwithstanding this, and even though the Longstaff and Schwartz model has more variables and might thus be expected to provide a closer fit, Wei and Guo find that the Merton model generates credit structures more comparable to observed structures.

It is noted that Wei and Guo apply the Longstaff and Schwartz and Merton models to Eurodollar data, which is not firm specific. Accordingly, their analysis is directed more toward market-wide pricing of credit risk, as opposed to examining the power of the Merton model on a firm-by-firm basis. Indeed, application of any option-based model using "average" data may be problematic as such models are not linear.

3.2.1.6 Barth, Landsman and Rendleman (1998)

Barth, Landsman and Rendleman (1998) use an option pricing-based approach to analyse the value of the components of corporate debt (e.g. call, put, conversion and sinking fund features). Their work is motivated by the possible need for firms to separately disclose the fair value of the primitive components embedded in compound financial instruments. The data sample is publicly traded US firms with 31 December 1990 fiscal year ends having, amongst other criteria, at least one publicly traded bond and a ratio of convertible securities to total debt plus preferred stock in excess of 10%[6].

Barth, Landsman and Rendleman model the firm's equity as an option, but using a binomial model rather than the Black-Scholes OPM, and solve for the

[6] In contrast to most direct tests of the Merton model, the authors were screening to include firms with complex debt structures, to analyse the pricing of the components of the complex debt securities.

implied volatility that minimises the sum of the squared deviations between observed (i.e. market) and estimated values for the firm's debt and equity. Their binomial model is more complex than the basic Merton model as it incorporates the various features of the firm's debt issues, although the risk-free term structure is still assumed to be fixed.

As an indirect test of their bond pricing model they compare the equity volatility implied by their model with:

1. Historical equity volatility;
2. One-year-ahead realised equity volatility; and
3. Equity volatility implied by prices of traded call options over firms' common stock.

The equity volatility estimates from their model are over twice as high as those from any of the above three benchmarks. Barth, Landsman and Rendleman note that this means their bond pricing model estimates, of bond values, may not be reliable. They postulate that this could be because their model does not incorporate interest rate risk, although when they test for interest rate risk proxies these are unable to explain the difference between their volatility estimates and the other volatility measures.

3.2.1.7 Helwege and Turner (1999)

Helwege and Turner (1999) examine the credit spread term structure for speculative grade issuers (i.e. non-investment grade debt or "junk" bonds). They postulate that prior research into the term structure of credit spreads (Sarig and Warga, 1989; Fons, 1994) did not control for differences in credit quality within credit ratings. Specifically, that higher quality issuers within a given credit rating category are more likely to issue debt of longer maturity. Hence inducing a bias towards lower credit spreads with longer term to maturity, within any given credit rating category, and thus a downward sloping

credit spread curve – such effect being more pronounced with lower rated debt.

After controlling for differences in credit quality within credit rating categories, by using matched pairs of bonds of the same rating but different maturity issued by the same firm on the same day, Helwege and Turner find no evidence of downward sloping credit spread curves for speculative grade issuers. They note that the downward sloping credit spread curves predicted by the Merton model, for highly leveraged firms, are only likely to arise using assumed leverage ratios well in excess of those actually observed for most speculative grade issuers.

3.2.1.8 Anderson and Sundaresan (2000)

Anderson and Sundaresan (2000) undertake a comparative study of the Merton model and two extensions of that model: - Leland (1994) and a special case of the Anderson and Sundaresan (1996) and Mella-Barral and Perraudin (1997) models. Anderson and Sundaresan apply these models at the aggregate firm level using corporate bond yield indexes and (US) economy-wide firm data. In general terms they find that all three models can explain much of the variation in the historical time series of corporate bond yield indexes. However, the extensions of the Merton model are found to have greater explanatory power.

Anderson and Sundaresan (2000) note that prior attempts to apply the Merton model to price US corporate bonds (e.g. Jones, Mason and Rosenfeld, 1984) tended to underestimate observed yields when plausible asset volatility values are used. They find that to fit the Merton model to their data firm asset volatility is estimated at 0.9 times the volatility of the S&P 500 (equity) index. They interpret this as supporting the view that implausibly high asset volatility estimates are required to fit the Merton model to observed credit spreads. However, it is noted that Anderson and Sundaresan use a market-

wide estimate of equity volatility which (because the returns of the S&P 500 constituent stocks are not perfectly correlated) will be lower than the average equity volatility of the constituent firms for the market index they use, hence their asset volatility estimates could be somewhat less than 0.9 times average firm equity volatility. Anderson and Sundaresan conclude that their study is exploratory in nature and could be extended by using a stochastic risk-free structure, allowing for a liquidity premium and using firm specific measures of leverage and asset volatility.

3.2.2 Credit Rating Prediction

3.2.2.1 Trussel (1997)

Trussel (1997) applies the Merton model to predict the probability of a firm defaulting, for which the firm's credit rating is used as a proxy. He shows that one minus the probability of a firm defaulting is equal to $N(d_2)$ from the Black-Scholes OPM, as applied to the firm, but uses the instantaneous rate of return on the firm's assets (μ) in place of *r*, the risk-free rate of return. To operationalise the model Trussel estimates the parameters as follows:

- S is taken as the observed market value of the firm's equity
- X the face value of the firm's debt is taken as the book value of the firm's debt
- V equals the sum of S and X
- μ is measured using the natural log of the price relative for the preceding 30 months
- σ_V is also measured using the natural log of the price relative for the preceding 30 months
- T is measured as the weighted average maturity of the firm's debt. Aging for each of the five years following balance date is obtained

from Compustat, all other debt is assumed to mature in the sixth year following balance date.

It is not apparent whether or not Trussel adjusts the face value of debt for the fact that typically firms' debt is coupon bearing (i.e. adjusting it to be the notional future value of a zero coupon bond – or the "exercise price"). Trussel's sample is firms in the Compustat database with the necessary data items (per above) and which have established or changed their S&P credit rating over the most recent 60 months.

For half of his sample Trussel regresses the Compustat numerical values for credit rating (2=AAA through 27=D) against the variables used to measure $N(d_2)$, being: - the natural logarithms of V and of X, μT and $1/2\sigma_V^2 T$ (as per equation (2) in this study, using μ in place of r). All four independent variables in the regression have the expected signs and three are statistically significant - the return variable is not found to be significant. The regression R^2 is 0.544 and the fitted model correctly classified the credit rating of 68% of the firms in the initial sample. The regression model correctly classified 66% of the credit ratings for the other half of the sample (i.e. the holdout sample).

Trussel then estimates default probability (measured as $1-N(d_2)$, or $N(-d_2)$), on the date at which each firm's credit rating was assigned or changed, and tests for the null hypothesis that the mean default probabilities are the same across all credit ratings. The null hypothesis is rejected; further statistical tests show that the mean probability of default is significantly higher for each successive reduction in credit rating.

Trussel concludes that the Merton model adequately captures the actual probability of default and also provides a reasonable estimate of the probability of default.

3.2.3 Credit Rating Changes

3.2.3.1 Delianedis and Geske (1999)

Delianedis and Geske (1999) test the ability of the Merton model and the Geske (1977) compound option model to estimate risk neutral probabilities of firms' defaulting on their debt. They estimate default probabilities in a similar manner to Trussel (1997), but unlike Trussel the rate of return on firms' assets is modelled as the risk-free rate – hence the estimated default probabilities are those in a risk neutral world. The Geske (1977) model is applied as if the firm's equity is a compound option, with the firm's short term debt being paid first (if after one year stockholders wish to keep their "option" over the firm's assets alive) and a final payment of all long term debt at a later date.

Short term debt is measured net of liquid current assets (cash, marketable securities and accounts receivable) and assumed to be due in six months. Long term debt comprises the Compustat items: - debt due in 1, 2, 3, 4 and 5 years (which is assigned the corresponding maturity), long term debt, deferred taxes, minority interest and other long term liabilities (which are assumed to mature in 10 years, unless otherwise explicitly stated). For the Merton model Delianedis and Geske then reposition all of each firm's debt to a single duration, using Macaulay duration.

A monthly time series of risk neutral default probabilities is then calculated using the Merton and Geske (1977) models for US firms (with the necessary data) over the period 1987 through 1996. In applying the Merton model V and σ_V are both treated as unknowns, which are solved for using equations (1) and (16), as set out in this study. The mean values implied, from fitting the Merton model, for firm leverage and asset volatility are 33% and 0.17 for firms with investment grade ratings and 45% and 0.274 for firms with non-investment grade ratings.

Using their monthly time series of risk neutral default probabilities Delianedis and Geske then examine rating changes as an event study – to see if the Merton and Geske (1977) models are able to use market data to predict credit rating changes. They find that both models perform well. Their application of the Merton model shows statistically significant changes in risk neutral default probabilities for firms that undergo credit rating changes, up to 12 months in advance for investment grade firms and up to 24 months in advance for non-investment grade firms. They also find that within rating classifications firms with higher (lower) risk neutral default probabilities are more likely to experience a rating downgrade (upgrade) two, or four, quarters later.

3.2.4 Ex-dividend Stock Price Behaviour

3.2.4.1 French, Varson and Moon (1999)

French, Varson and Moon (1999) propose that the option-theoretic view of the firm provides an explanation of why stock prices for leveraged firms should drop on ex-dividend dates by less than the amount of the dividend (given that other theories are unable to fully explain ex-dividend stock price behaviour). They find that the dividend drop off for firms with nil long term debt is not significantly different from one, while for those firms with long term debt the drop off is less than one, as they hypothesised.

French, Varson and Moon then regress ex-dividend day stock returns against a number of variables, including firm leverage. The regression coefficient for leverage is positive (as expected) and also statistically significant. While their research is not a direct test of the Merton model, it provides support for the option-theoretic view of the firm.

3.2.5 Market Valuation of Bankrupt Firms

3.2.5.1 Russel, Branch and Torbey (1999)

Russel, Branch and Torbey (1999) use the Black-Scholes OPM/Merton model to value the equity in firms that have filed for bankruptcy. They postulate that the equity of such firms has option-like characteristics, which explains why the stock in these firms can trade at, seemingly, irrationally high - or indeed at any - prices (i.e. when the face value of liabilities exceeds the value of assets).

To apply the OPM Russel, Branch and Torbey use the following inputs: - the book value of the firm's assets at the date of filing (V), the book value of total liabilities at the same date (X), time to maturity of the option of 120 days[7] (T), the annualised T-bill rate in the month of filing (r) and the firm's equity volatility over various periods leading up to the bankruptcy filing (as a proxy for the firm's asset volatility, σ_V). They note that their method of volatility estimation is likely to result in values for σ_V that are upwardly biased. Their mean estimates for σ_V range from to 1.136 to 2.067, which compare, for example, with a mean σ_V estimate of 0.274 in Delianedis and Geske (1999) for firms with non-investment grade ratings.

The option-based equity values derived by Russel, Branch and Torbey are significantly higher than observed market prices for traded equity in the bankrupt firms in their sample. They then try different approaches to "write down" the book value of assets, to what could be values more in line with market values, before applying the option model. Their results suggest that a write down of between 20% and 40% would result in mean option model values of equity in line with mean observed market prices. However, it may be that had Russel, Branch and Torbey used lower (perhaps more realistic)

[7] Used in most of their analysis – being the exclusive period during which a reorganisation plan is typically proposed in the US.

σ_V estimates they would also have been able to generate more realistic equity valuations of bankrupt firms using the OPM.

3.2.6 Bankruptcy Prediction

3.2.6.1 Charitou and Trigeorgis (2000)

Charitou and Trigeorgis (2000) examine 139 US firms that filed for bankruptcy between 1983 and 1994, paired with matched firms of the same size and from the same industry. They use the Merton model, modified to allow for continuous debt servicing payouts. I.e. r in the model is replaced with r minus debt servicing as a percentage of firm value (D). They also test a variation of the Geske (1977) compound option model. To implement the Merton model they estimate the parameters as follows:

- S is taken as the observed market value of the firm's equity
- X the face value of the firm's debt is taken as the book value of the firm's debt (B)
- V equals the sum of S and X
- σ_V is measured using the monthly changes in firm value over the preceding 36 months
- T is measured as the weighted average duration of the firm's debt
- r-D is estimated using the 3-month US T-bill rate for r and the firm's annual coupon interest as a proportion of V for D.

It is noted that their use of X=B is appropriate since the (risk neutral) firm drift rate has been adjusted for debt servicing prior to time T.

Charitou and Trigeorgis find that the probability of default under the Merton model, $N(-d_2)$, is significantly different between the bankrupt firms and the control group one, two and three years prior to bankruptcy. Using

multivariate regression they also find that the variables underlying $N(-d_2)$, other than *r-D* (i.e. natural log of *V*, natural log of *B*, asset volatility σ_V and time to maturity *T*), are all statistically significant one year prior to bankruptcy. Their implementation of the Geske (1977) model increases explanatory power, but without diminishing the significance of the primary Merton model variables.

Charitou and Trigeorgis then conduct tests using a holdout sample and find that use of $N(-d_2)$ from their implementation of the Merton model is able to predict bankruptcy in 70.1%, 62.3% and 65.7% of cases one, two and three years in advance. A model fitted to the variables underlying $N(-d_2)$ is able to predict bankruptcy in 78%, 66.7% and 65.8% of cases one, two and three years in advance.

Charitou and Trigeorgis conclude that an option-theoretic framework has significant explanatory power in predicting bankruptcy.

3.2.7 Summary of Tests of the Merton Model

A common finding from testing the Merton model is that to fit the model to observed corporate bond prices higher than reasonable estimates of σ_V are required. Jones, Mason and Rosenfeld (1984) find that when they tested the Merton model to price corporate bonds, regression tests on the bond pricing errors suggest that their firm variance estimates were over-stated. Ogden (1987) finds, for his sample, that the mean corporate bond yield premium predicted by the Merton model is only 57% of the mean observed yield premium. Ogden uses firm volatility estimates consistent with observed equity volatility estimates. Barth, Landsman and Rendleman (1998) find that the implied equity volatility estimates used to solve their Merton-based bond pricing model are over twice as high as equity volatility measures observable in the market. Against this Russel, Branch and Torbey (1999) use, what they

acknowledge to be, upwardly bias estimates of σ_V to estimate equity values for bankrupt firms, which are then found to be greater than observed equity values.

Ogden (1987) concludes that the Merton model may be mis-specified with regard to its assumption of firm scale invariance. This suggests that a size factor may perhaps be required to complement the Hsia approach in explaining the variation in stock returns. Alternatively, fitting the Merton model to observed credit spreads may subsume any size factor into the variables used to solve the Merton model.

Ogden (1987) also concludes that the Merton model may be mis-specified by assuming non-stochastic interest rates. Yet when Wei and Guo (1997) test an alternative model which allows for stochastic interest rates they find that the simpler Merton model performs better.

Sarig and Warga (1989), and Fons (1994) find evidence that the shape of the credit spread term structure for different quality issuers is as predicted by the Merton model. However, when Helwege and Turner (1999) control for credit quality within credit ratings they find no evidence of hump shaped or downward sloping credit spread curves. They note that the leverage ratios required to produce such shapes are not usually observed in the real world.

It is noted that most researchers who test Merton-based models screen their company samples to include only those firms with relatively simple capital structures.

In conclusion, empirical tests of the Merton model are supportive of the general predictions of the model. But fitting the model to observed credit spreads typically requires over-estimation of the volatility of the returns on the firm's assets. This may have implications for using the fitted Merton model in applying the Hsia approach.

3.3 Empirical Tests of the Hsia Approach

An extensive search of the literature uncovered only one study attempting to implement the Hsia (1991) approach to estimating firms' cost of equity, Corrado and Miller (1995). At the time of writing it had not been possible to obtain a copy of this working paper , but one of the authors, Corrado, was contacted. He advised that he tried and tried to get the Hsia approach to work, but that it never yielded consistent results.

Attempts were also made to contact Hsia, who has now retired from academia (to enquire as to empirical testing of his suggested approach), but no reply was received.

3.4 Asset Pricing Benchmarks

A conventional benchmark against which to compare the power of an asset pricing model has been the CAPM. However, the CAPM itself is not without its critics.

A turning point is probably Fama and French (1992). They find firm size is highly correlated with beta and that, after controlling for this, beta has little power to explain the cross-sectional variation of stock returns. The combination of firm size and the book-to-market ratio is found to dominate the role of beta in explaining the cross-sectional variation of stock returns. Fama and French (1993) go on to test a three factor model for explaining stock returns, the three factors being: - a size factor, a book-to-market factor and a market factor (being the excess return on the market). They find that the addition of their size and book-to-market factors increases the explanatory power of their model.

It is beyond the scope of this study to examine the CAPM or the Fama-French three factor model in detail. However, to have any real relevance the

Hsia approach must be competitive with the performance of the CAPM and of the Fama-French three factor model.

Chapter 4

4 DATA AND METHODOLOGY

4.1 Specifying the Model Parameters

4.1.1 Overview

The data items required per Hsia (1991), to apply his approach, to estimate the cost of equity for an individual firm at any point in time, are:

1. market value of equity;
2. market value of debt;
3. the firm's cost of debt; and
4. risk-free rate of return.

Under the model specified as per equations (12) to (15) the risk-free rate of return is no longer needed, instead the firm's debt margin is required (this obviated the need to determine which maturity of risk free instrument should be used to fit the Merton model and then apply the Hsia approach). Hence the firm specific data items required for this study are:

1. market value of equity;
2. market value of debt;
3. the firm's debt margin; and
4. the firm's cost of debt (used to estimate the term of the debt, T).

The Hsia approach to estimating firms' cost of equity is applied for each firm using:

1. market value of equity as at 30 June (in year *t*), as obtained from Compustat;
2. book value of debt, as a proxy for market value of debt, as of the fiscal year ended in the previous calendar year (year *t*-1), as obtained from Compustat (i.e. the book debt values that would have been readily available by 30 June in year *t*);
3. the firm's cost of debt as at 30 June (in year *t*), as proxied by the yield on a corporate bond index of the same rating as the firm; and
4. the firm's debt margin as at 30 June (in year *t*), as proxied by the spread (over US Treasury securities of the same maturity) on a corporate bond index of the same rating as the firm at that date.

Monthly stock returns are obtained from Datastream[8]. Each month, from July in year *t* through June in year *t*+1, the cross-section of actual excess stock returns is regressed against the excess stock returns predicted for the firms in the sample using the Hsia approach (i.e. ex post actual excess returns are regressed against ex ante predicted excess returns). To examine the relative power of the Hsia approach the cross-section of ex post actual monthly stock returns for the sample firms is also regressed against other ex ante variables: - beta, firm size and the ratio of book-to-market value. For the latter purpose beta is estimated based on the Fama MacBeth (1973) methodology, while firm size and the ratio of book-to-market value are estimated using the approach in Fama and French (1992) (refer to the heading below **4.4 Benchmark Data**).

A more detailed description of the data and methodology used, including the rational for the approach taken, is now discussed below.

[8] Stock returns are calculated as: Closing Price/Opening Price – 1.

4.1.2 Company Sample

The company sample chosen to test the Merton model/Hsia approach was listed US firms in the Compustat database that had a credit rating (refer to the sub-heading below *4.1.5 Firms' Cost of Debt* for a discussion of this data item). The firms had to be listed so that the market value of their equity and stock returns were readily observable, while the credit rating was necessary to estimate each firm's cost of debt. All companies meeting these criteria with fiscal years ending between January 1986 and December 1998 were included in the initial sample. In the few instances where firms had two fiscal year ends in one calendar year (e.g. as a result of changing balance date), the latest fiscal year end data was used in all calculations.

The sample excluded financial companies (SIC #'s 6000-6999) and utilities (SIC #'s 4900-4999). In some instances it was not possible to clearly match companies between the Compustat (accounting variables and market value) and Datastream (stock returns) databases, in which case these companies were dropped from the sample.

4.1.3 Market Value of Equity

Market value of equity for each firm in the sample is taken from the Compustat monthly files as at the end of June in year t, for applying the Hsia approach, and as at the end of December in year t-1, for calculating each firm's size and its book-to-market ratio at June in year t (as per Fama and French, 1992).

Fama and French (1992) rationalise that by June in year t all firms will have filed annual reports for their fiscal year ended during the calendar year t-1, hence all accounting variables will be observable at June in year t. They measure market value at December in year t-1, rather than at each firm's fiscal year end, so that the cross-sectional variation in this ratio is not affected by market-wide movements during the calendar year. Fama and French (1992)

note that their approach means that the accounting variable in the numerator of the ratio is not aligned with the market value in the denominator, but they find that using fiscal year end market value has little impact on their tests.

In applying the Hsia approach the same logic is used as in Fama and French (1992) for selection of accounting variables (i.e. book value of debt), but the firm's leverage and its cost of debt appear to be critical inputs in applying Hsia's approach. Hence, these market-based parameters are selected as at June in year *t*. It is noted that this might place the size and book-to-market variables at a disadvantage vis-à-vis the Hsia approach.

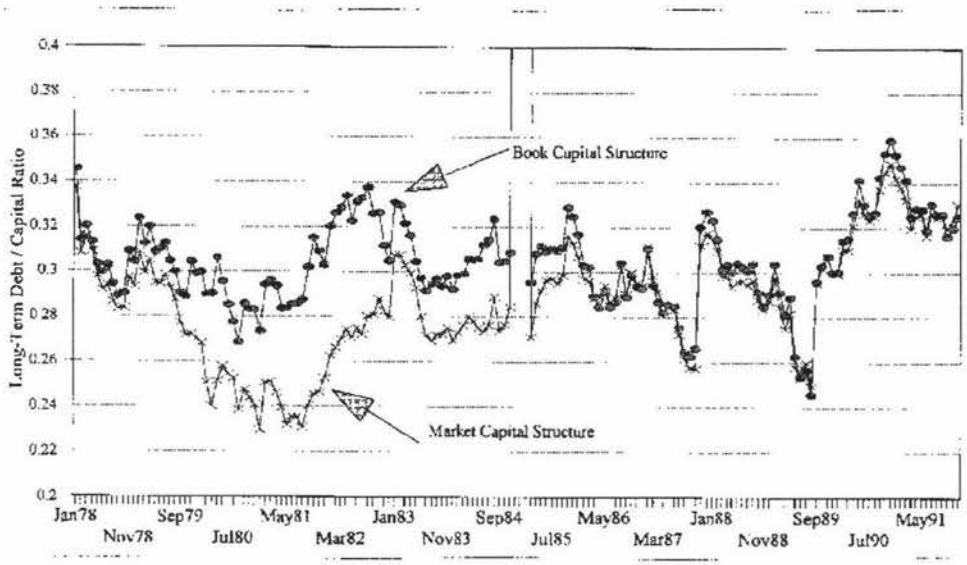
The market value of equity is for common stock only. It does not include the value of convertible debt, preferred stock or warrants.

4.1.4 Market Value of Debt

As the market value of debt for all of each firm's debt is generally considered to be unobservable the book value of each firm's debt is used as a proxy for the market value of debt.

Sweeney, Warga and Winters (1997) study the problems that can arise from using book value of debt as a proxy for market value in empirical work. In terms of equation (12), a misestimation of the value of the firm's debt will introduce an error to the estimation of the firm's excess return on equity. The Sweeney, Warga and Winters (1997) study covered the period 1978 to 1991. For their sample of US firms the difference between book and market value of debt is most pronounced in the first half of the period they study (1978-1984), which pre-dates the period used for this study. This provides some comfort that any error introduced through using book value of debt may not be as pronounced as it could have been in the past. Refer below to the chart produced by Sweeney, Warga and Winters (1997) [their Figure 1, p. 9]:

Figure 2
Long-term Debt to Capital



Sweeney, Warga and Winters (1997) note that the difference between the book and market values of debt tends to be higher when interest rates are high (as was the case in the early 1980s). Long term US government bond rates for the period covered by this study have remained at or below the rates prevalent during the second half of the Sweeney, Warga and Winters (1997) study – when the gap between book and market value of debt was less pronounced. This provides some comfort that any error introduced through using book value of debt for this study, instead of market value, may not be significant.

Interest bearing debt comprises Long Term Debt – Total (Compustat annual data item #9) and Debt in Current Liabilities (Compustat annual data item #34). The presence of convertible debt and/or preferred stock in a firm's capital structure is not accommodated in the basic Merton model/Hsia approach. Accordingly all firms with preferred stock (Compustat annual data items #10, 56 or 130) and/or convertible stock (Compustat annual data item #79) in their capital structure are excluded from the sample.

Firms with a book value of interest bearing debt less than 1% of the combined book value of interest bearing debt plus market value of equity were excluded from the sample, on the basis that the option-theoretic model of the firm is not applicable to firms with a nil or negligible "exercise price".

4.1.5 Firms' Cost of Debt

The firm's annual debt servicing cost (divided by the book value of debt) is advocated by Hsia (1991) as the method to estimate the firm's cost of debt. This approach potentially suffers from several deficiencies, for example:

1. End of fiscal year debt (or even average of beginning of year and end of year debt) may not reflect the actual average level of debt throughout the fiscal year;
2. Some of the firm's debt may have been issued at fixed rates of interest, which could differ from market rates current at the end of the fiscal year[9];
3. The firm's creditworthiness may have changed between the time interest rates were fixed on its debt and the end of the fiscal year; and
4. The maturity structure of the firm's debt is not readily observable[10], hence even if the cost of debt can be measured with precision it will not be easy to match this to the risk-free term structure to obtain a precise estimate of the firm's borrowing margin (as noted above the Hsia approach implicitly requires an accurate estimate of the firm's borrowing margin rather than just its absolute cost of debt).

The preferred measure of each firms' cost of debt is the weighted average yield on all of its outstanding debt at each date the Hsia approach is being applied. However, for most firms this information is not readily observable.

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[9] Although in applying the Merton model/Hsia approach this need not be a problem if the market value of the debt is also treated as being its book value.

[10] For example, only limited debt aging information is included in Compustat. This study did not attempt to use that information.

Many firms have no debt instruments traded in the secondary market. While some firms do have traded bonds, these would normally only comprise part of a firm's overall debt. Further, thin trading in corporate bonds can mean that much "price" information is in fact derived from dealer quotes, rather than actual trades, or from dealers' "matrix prices". Warga and Welch (1993) discuss the problems in obtaining reliable corporate bond price data.

In light of the above difficulties in obtaining reliable estimates of firms' cost of debt, an alternative implementation of Hsia's approach is proposed. This is explained in detail in the following section.

4.1.5.1 Credit Rating Based Approach

Credit rating information is available for many US firms. For example, Moody's, S&P and Fitch IBCA provide credit ratings on US firms. Through until 1 September 1998 Compustat records the S&P Senior Debt Rating for an indicative senior debt issue, where one is available or is otherwise implied where only junior debt is rated. From 1 September 1998 Compustat records the S&P Long-Term Domestic Issuer Credit Rating, where one is available. It is assumed that both types of rating provide a reasonable proxy for the overall average rating of all a firm's debt.

Indexes are also published of the yields (and other characteristics) of bonds issued by US firms, classified by bond rating. US corporate bond indexes are complied and provided by several organisations, including Lehman Brothers and Merrill Lynch. Accordingly it is feasible to estimate the average cost of debt for a firm, at point in time, by reference to that firm's credit rating and the then current average yield on corporate bonds with the same credit rating (as represented by an index). Clearly this approach could also be problematic, for example:

1. A firm's indicative senior credit rating, or issuer credit rating, may not reflect the average creditworthiness of all of its outstanding debt.
2. At any point in time a firm's credit rating may not reflect all current market information. This can arise if creditworthiness has changed, but the rating agencies have not yet revised their ratings. Delianedis and Geske (1999) find evidence that the equity market anticipates impending credit rating changes 12 to 24 months in advance;
3. The averaging process used in constructing the corporate bond indexes is likely to mask differences in individual firm's bond yields within each rating band; and
4. Corporate bond indexes are often constructed using both callable and non-callable bonds, refer Duffee (1998). The presence of these features affects the market value of the constituent bonds and hence contaminates the yield information contained in the indexes.

The method used in this study to estimate a firm's cost of debt is to use the yield on a corporate bond index of the same credit rating as the firm. The primary corporate bond indexes used are the Lehman Brothers Corporate Bond Indexes, for bonds of long maturity. These indexes commenced in January 1973 for US dollar denominated corporate bonds with Moody's' credit ratings of Aaa, Aa, A and Baa (i.e. investment grade bonds). From March 1990 Lehman Brothers introduced indexes for US dollar denominated corporate bonds with S&P credit ratings of BB, B and CCC (i.e. non-investment grade or "junk" bonds). From January 1993 Lehman Brothers introduced a further index for US dollar denominated corporate bonds with S&P credit ratings of CC to D.

Prior to March 1990 Merrill Lynch compiled a US corporate non-investment grade bond index, its High Yield Master II index, for US dollar denominated corporate bonds with Moody's, or S&P equivalent, credit ratings of Ba, B and

Caa. This index commenced in September 1986 and provides a basis for supplementing the information available from the Lehman Brothers indexes.

The commonly accepted mapping between the Moody's and S&P long term credit rating categories, together with the Compustat identification number for the latter, are as set out in Table 1 below. Both Moody's and S&P modify some of their letter ratings, by the addition of a number or a plus/minus sign, to show relative standing within each major rating category.

Table 1
Credit Rating Definitions

Moody's Rating	S&P Rating	Compustat #	S&P/Compustat Description
Aaa	AAA	2	"AAA" indicates the highest rating assigned by S&P. Capacity to pay interest and repay principal is extremely strong.
Aa1	AA+	4	"AA" indicates a very strong capacity to pay interest and repay principal. There is only a small degree of difference between "AAA" and "AA".
Aa2	AA	5	
Aa3	AA-	6	
A1	A+	7	"A" indicates a strong capacity to pay interest and repay principal. They are, however, somewhat more susceptible to adverse effects of changes in circumstances and economic conditions than "AAA" or "AA" debt issues.
A2	A	8	
A3	A-	9	
Baa1	BBB+	10	"BBB" indicates an adequate capacity to pay interest and repay principal. Although it normally exhibits adequate protection parameters, adverse economic conditions or changing circumstances are more likely to lead to a weakened capacity to pay interest and repay principal than debt issues with higher ratings.
Baa2	BBB	11	
Baa3	BBB-	12	
Ba1	BB+	13	"BB" indicates less near-term vulnerability to default than other speculative issues. However, they face major ongoing uncertainties or exposure to adverse business, financial or economic conditions that could lead to inadequate capacity to meet timely interest and principal payments. S&P also uses the "BB" rating for debt subordinated to senior debt that is assigned an actual or implied "BBB"- rating
Ba2	BB	14	
Ba3	BB-	15	

Table 1 (continued)

Moody's Rating	S&P Rating	Compustat #	S&P/Compustat Description
B1 B2 B3	B+ B B-	16 17 18	"B" indicates a greater vulnerability to default but currently have the capacity to meet interest payments and principal repayments. Adverse business, financial, or economic conditions will likely impair capacity or willingness to pay interest and repay principal. S&P also assigns the "B" rating to debt subordinated to senior debt that is assigned an actual or implied "BB"- rating.
Caa1 Caa2 Caa3	CCC+ CCC CCC-	19 20 21	"CCC" indicates an identifiable current vulnerability to default and is dependent upon favourable business, financial, and economic conditions to meet timely payment of interest and repayment of principal. In the event of adverse, business, financial, or economic conditions, "CCC" issues are not likely to have the capacity to pay interest or repay principal. S&P also assigns the "CCC" rating to debt subordinated to senior debt that is assigned an actual or implied "B" or "B"- rating.
Ca	CC	23	"CC" is typically applied to debt subordinated to senior debt that is assigned an actual or implied "CCC" rating
C	C	24	"C" is typically applied to debt subordinated to senior debt that is assigned an actual or implied "CCC"- rating. S&P also assigns the "C" rating for situations in which a bankruptcy petition has been filed, but debt service payments continue.
Not applicable	CI	26	"CI" is reserved for income bonds on which no interest is paid.
Not applicable	D	27	"D" indicates that payment is in default. S&P assigns the "D" rating when interest payments or principal payments are not made on the date due even if the applicable grace period has not expired, unless S&P believes that such payments will be made during such grace periods. S&P also assigns the "D" rating upon the filing of a bankruptcy petition if debt service payments are jeopardised.
Not applicable	Not meaningful	28	Not meaningful.
Not applicable	SD	29	"SD" (Selective Default) is assigned when Standard & Poor's believes that the obligor has selectively defaulted on a specific issue or class of obligations in a timely manner.
Not applicable	Suspended	90	S&P suspended the bond rating on a class of debt.

Note: Compustat numbers 1, 3 and 25 are unassigned.

4.1.5.2 Calculation of Borrowing Margins

Each Lehman Brothers month end corporate bond index observation is converted to a credit spread as follows:

1. The index redemption yield is converted to a continuously compounding yield.
2. A continuously compounding risk-free rate is computed for a term equal to the average life of the corporate bonds in the index that month (refer below).
3. That month's credit spread or borrowing margin, for that bond rating, is calculated by deducting (2.) above from (1.) above.

4.1.5.3 Risk-Free Rate of Return

Historical US risk-free rate data was obtained from the US Federal Reserve Board (FRB) web site[11]. These are annualised rates[12] calculated by the FRB from the US Treasury bond yield curve for US Treasury bonds with constant maturities of 1, 2, 3, 5, 7, 10, 20 and 30 years.

From these FRB spot rates, forward rates are calculated between consecutive maturities. All interest rates are converted from annualised yields to continuously compounding yields, as appropriate for use in the Merton model.

4.1.5.4 Review of Borrowing Margins

The borrowing margin estimates derived using the process described above were perused for instances of negative margins or for where the margin in any month was lower for a low grade of debt than for a high grade debt A small number of such anomalies were noted and queries were made of Datastream,

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[11] http://www.federalreserve.gov/releases/H15/data.htm

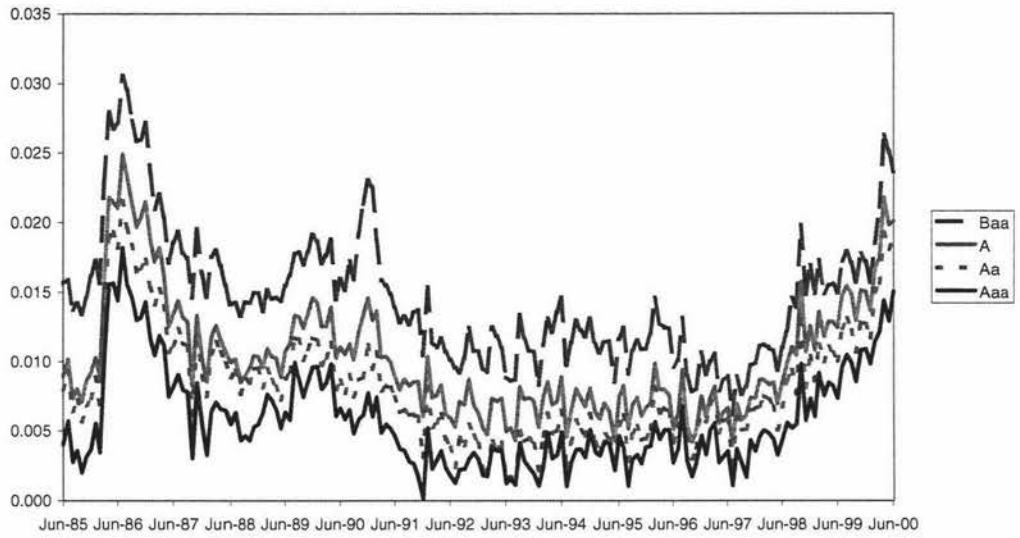
[12] In contrast to the way in which US T-bill prices are quoted, these Treasury bond rates are true yields.

who in turn contacted Lehman Brothers. The reason given for such anomalies is that the bonds included in the indexes can include call features, which are not explicitly priced (i.e. are not adjusted for) in constructing the indexes. However, none of these occurrences were at the end of June in any year, so have no direct impact on this study. In those months where anomalies were found the data is smoothed for the purpose of examining the relationship between the Lehman Brothers and Merrill Lynch indexes (refer Appendix A).

In the case of the Lehman Brothers index for CC to D rated corporate bonds, the credit spreads are found to fluctuate widely and, in many instances, to be implausibly low. This index is not considered to be a good proxy for estimating the borrowing margin of CC, C and D rated issuers hence firms with these credit ratings are excluded from the analysis.

Figure 3, below shows the resulting monthly spreads for the Lehman Brothers investment grade bond indexes over the period June 1985 through June 2000.

Figure 3
Investment Grade Bond Index Spreads

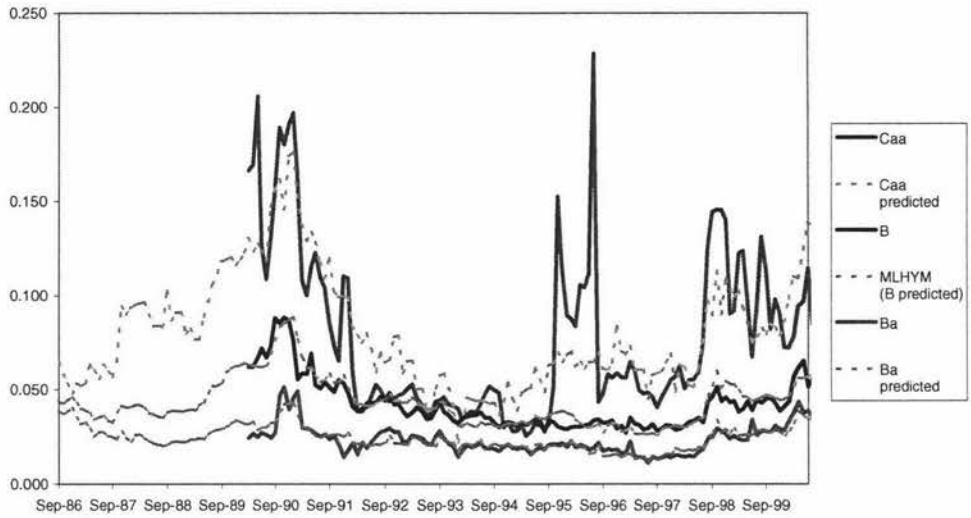


4.1.5.5 Supplementing the Lehman Brothers Non-investment Grade Bond Indexes

To supplement the Lehman Brothers index data set for non-investment grade bonds (Ba, B and Caa) prior to March 1990, information is used from the Merrill Lynch High Yield Master II index (MLHYM). Further details are provided in Appendix A.

Figure 4 shows monthly observations of the actual spreads for the MLHYM index and the Lehman Brothers non-investment grade bond indexes and the predicted spreads for the Lehman Brothers non-investment grade bond indexes over the period September 1986 to September 2000.

Figure 4
Non-investment Grade Bond Index Spreads



From examining the chart, the use of the spread on the MLHYM index as a proxy for the spread on the Lehman Brothers B corporate bond index is confirmed as being reasonable, as is the use of the Ba spread predicted from the regression equation. However, the "predicted" Caa spread is a much poorer fit against the actual spread on the Lehman Brothers Caa index. The high level of volatility in the actual Caa spread is noticeable. In any event after selecting the final sample only two firm-year observations (out of 4,019) relied on use of these "predicted" non-investment grade bond spreads.

4.1.5.6 Rating Modifiers

Since the Compustat bond rating data item is to the level of rating plus modifier, the index derived rating spread data set is also adjusted to differentiate credit spreads at the modifier level. No adjustment is made to the Aaa/AAA spread as neither Moody's nor S&P apply a modifier within this rating group. The remaining rating letters are split into three sub-groups

(in line with the number of modifiers applied by Moody's and S&P) on the assumptions that:

1. A simple average of the three modified spreads equals the spread for that letter. Hence the middle sub-group, which carries no modifier, has the same spread as the unmodified rating.
2. The credit spreads for the +/- modifiers are one third of the distance to the nearest adjacent letter.

Following the above process, June spread data is available for Aaa, Aa, A, Baa, Ba, B and Caa corporate bond indexes, with modifiers, for the 13 years from 1987 through 1999.

While the pre-processing of the spread data used in this study is relatively extensive, this is considered worthwhile because of the perceived sensitivity of the Hsia approach to the borrowing margin or spread input and also to maximise the size of the sample on which the Hsia approach is tested.

4.1.6 Calculation of Corporate Bond Term

Each monthly corporate bond index yield observation was converted to a notional bond term or duration as per Hsia (1991), as follows:

$$Term = {}^{1}\!/_{Yield} \tag{18}$$

where the yield is expressed on a continuously compounding basis.

In the case of the "predicted" Ba and Caa margins (as discussed above) "predicted" yields thus also need to be derived. These were estimated by adding/subtracting the difference between the "predicted" margin and the actual margin for the adjacent rating indexes, to the yield of those adjacent rating indexes, then averaging the result (i.e. by reference to the Baa and B

yields to derive a notional Ba yield, and by reference to the MLHYM/B yields to derive a notional Caa yield).

4.2 Running the Model

After the data is processed, as described above, the following model inputs are available for each company in the sample as at June in year *t*:

1. Market value of equity (measured as at June in year *t*);
2. Book value of debt (measured as of the fiscal year end that ended in year *t*-1);
3. Term of debt (estimated as at June in year *t*); and
4. Borrowing margin (estimated as at June in year *t*).

For each firm equation (13) is then solved for σ_V, for each June between 1987 and 1999 for which all of the model inputs are available in the data set.

Boundary values of 1% and 250% are first tested for σ_V. If the market value of the firm's equity falls outside the Merton model equity values using these values then the search process is terminated, on the basis that the model can not be solved or requires an implausibly high volatility parameter. None of the firms in the sample in fact breached these boundaries.

Following this screening an initial value for σ_V, σ_V^i, is chosen based on the method proposed by Manaster and Koehler (1982), adapted to the formulation of equation (13), as follows:

$$\sigma_V^i = \sqrt{\left|\ln\left(\frac{V}{B}\right) + mT\right| \frac{2}{T}} \tag{19}$$

In subsequent iterations, values of σ_V are estimated using the Newton-Raphson method (see Manaster and Koehler, 1982; Haug, 1998). For the n^{th} estimate:

$$\sigma_V^{n+1} = \sigma_V^n - \frac{S_{\sigma_V^n} - S}{SN(d_1)\sqrt{T}} \tag{20}$$

where:

$S_{\sigma_V^n}$ and $N(d_1)$ were estimated using σ_V^n.

This iterative procedure is stopped once:

$$\frac{\left|S_{\sigma_V^n} - S\right|}{S} < \varepsilon \tag{21}$$

with ε set at 0.000001 or after 500 iterations, whichever occurs first. For each observation, the final value of $N(d_1)$ is then used, in conjunction with the values for *m*, *B* and *S*, to estimate the expected excess return on equity, as per equation (12). These excess return estimates are continuously compounding annual rates. They are divided by 12, and then converted from continuously compounding to simple periodic rates (using the exponential function) to provide Hsia-based estimates of monthly excess returns.

4.3 Computing Realised Excess Returns

Realised monthly excess stock returns are calculated by deducting the one month T-bill return, for the month, from the stock return for the same

month. The monthly stock returns are calculated using the Datastream Total Return Index for each stock[13]. The T-bill data is from Ibbotson Associates.

4.4 Benchmark Data

To compare the ability of the Hsia approach to explain the cross-section of stock returns to that of the CAPM and the Fama-French three factor model, additional data items are required for each firm in the sample: - beta, market value of equity and the book-to-market ratio.

4.4.1 Beta Estimation

Betas are estimated using the Fama and MacBeth (1973) methodology, except that the betas are estimated using full post-ranking portfolio returns, as per Chan and Chen (1988), and Fama and French (1992). Pre-ranking betas are measured, using 24 to 60 previous months' stock return data, for all stocks in the initial sample. The initial sample comprises all firms with a Compustat recorded credit rating at anytime between 1986 and 2000 and a minimum of 24 preceding months' stock return data in Datastream. The stock market index used is the value-weighted US stock market index constructed by Fama and French[14]. Monthly stock returns are calculated using the Datastream Total Return Index for each stock[15].

At June in year t all firms in the sample are sorted into 10 portfolios based on their pre-ranking betas. For the subsequent 12 months (July in year t through June in year t+1) monthly returns are calculated for each portfolio. The portfolio formation process is then repeated each subsequent year. The full post-ranking portfolio returns are then regressed against the stock market

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[13] Calculated as: Closing Price/Opening Price – 1.

[14] Obtained from Ken French's data library: - http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

[15] Also calculated as: Closing Price/Opening Price – 1.

index in order to obtain a beta estimate for each portfolio. Each stock is then assigned the portfolio beta for the period it is sorted into a particular portfolio (i.e. if the stock moves into a different portfolio group it will then be assigned a different beta).

Unlike Fama and French (1992) there is no pre-sorting on the basis of firm size. It is beyond the scope of this study to examine the relative performance of beta versus size in explaining the variation in the cross-section of returns. Rather, the combined performance of the three Fama-French factors (beta, size and book-to-market) is used as one benchmark against which to measure the Hsia approach.

4.4.2 Market Value of Equity

As per Fama and French (1992) the market value of equity is expressed as the natural logarithm of the market value of equity, measured in millions of dollars. Market value is measured for this purpose as at the end of December in year t-1, also as per Fama and French (1992). The data source is Compustat.

4.4.3 Book-to-market Ratio

As per Fama and French (1992) the book value of equity is measured at the fiscal year ended in year t-1 and the market value of equity is measured as at the end of December in year t-1 (as per the above paragraph). The natural logarithm of the book-to-market ratio calculated from these figures is then used to examine stock returns from July in year t through June in year t+1.

As per Fama and French (1993), and their subsequent papers, the book value of equity is measured using Compustat data items; stockholders' equity (#216), plus balance sheet deferred taxes and investment tax credits (#35), minus the book value of preferred stock. Depending on availability the

redemption (#56), liquidation (#10) or par value (#130) (in that order) is used to estimate the book value of preferred stock.

4.4.4 Effect on Final Sample Selection

Not all firms for which the Hsia approach can successfully be applied in June in year *t* also have beta, size and book-to-market data available at June in year *t*. Hence the CAPM and Fama-French three factor model are tested against sub-sets of the full sample. The final sample size for which the Hsia approach is applied is 4,019 firm-years. Subsequent monthly stock returns, over the following 12 months, are not always available for all firms resulting in 46,553 firm-month observations being available for the cross sectional regressions.

4.5 Cross-Sectional Regression Equations

4.5.1 Hsia Approach

The cross-sectional regression equation for testing the Hsia approach to estimating the excess return, for firm *j*, is:

$$R_j - r = \gamma_o + \gamma_1 E\left(R_j^H - r\right) + \varepsilon_j \qquad (22)$$

where:

- R_j is the ex post return on stock *j* for the period
- r is the return on the risk free asset for the period
- γ_0 is the constant from the regression, with an expected mean value of zero if the model is able to fully explain the cross-sectional variation in stock returns
- γ_1 is the slope from the regression on the expected excess return for stock *j*, as estimated using the Hsia approach. The slope is expected

to be statistically significant if the Hsia approach has a role in explaining returns. If the Hsia approach has perfect predictive power (for predicting excess stock returns), then the slope coefficient will be 1.0

$E(R_j^H - r)$ is the ex ante expected excess return for stock *j*, as estimated using the Hsia approach.

ε_j is the regression error term.

4.5.2 Fama-French Three Factor Model

A cross-sectional regression equation for testing the three factor Fama-French model, for firm *j*, is:

$$R_j - r = \gamma_2 + \gamma_3 \beta_j + \gamma_4 \ln(ME_j) + \gamma_5 \ln(BE_j / ME_j) + \varepsilon_j \qquad (23)$$

where the additional terms are:

γ_2 is the constant from the regression, with an expected mean value of zero if the model is able to fully explain the cross-sectional variation in stock returns

γ_3 is the slope from the regression on the stock betas, expected to be statistically significant if beta has a role in explaining returns

β_j is the covariance of the returns for stock *j* with the returns for the market (i.e. stock *j*'s beta)

γ_4 is the slope from the regression on the stocks' size

$\ln(ME_j)$ is the natural logarithm of stock *j*'s market value, as measured in millions of dollars

γ_5 is the slope from the regression on stocks' book-to-market ratio

$\ln(BE_j/ME_j)$ is the natural logarithm of stock j's book-to-market ratio.

4.5.3 CAPM

Similarly, a cross-sectional regression equation for testing the CAPM is simply:

$$R_j - r = \gamma_6 + \gamma_7 \beta_j + \varepsilon_j \tag{24}$$

where the coefficients are:

- γ_6 is the constant from the regression, with an expected mean value of zero if the model is able to fully explain the cross-sectional variation in stock returns
- γ_7 is the slope from the regression on the stock betas, expected to be statistically significant if beta has a role in explaining returns.

4.5.4 Economic versus Statistical Significance

Unlike the regression equation used to test the Hsia approach, the regression coefficients of the independent variables for the Fama-French three factor model and for the CAPM are not expected to have values of 1.0 if these models have perfect predictive power. Rather the slope coefficients in these equations represent risk premia. Accordingly, in an economic sense the slope coefficient from the regression equation used to test the Hsia approach cannot be compared on a like-for-like basis with those from the equations used to test the other models. However, the statistical significance of the variables in all of the equations can still be compared, as a measure of the ability of each model to explain the cross-sectional variation in realised stock returns. In this context the Hsia-based expected excess returns can be viewed as a relative risk metric (i.e. assuming a linear relationship between risk and expected return).

4.5.5 Ex Ante versus Ex Post Returns

In common with most asset pricing tests this study tests ex ante return and risk measures against ex post realised returns. Ideally the ex ante return and risk measures would be tested against true ex ante return expectations, which are unobservable. Through using ex post returns, the random shocks that affect realised returns inevitably reduce the ability of any ex ante model to be properly tested.

Chapter 5

5 ANALYSIS AND RESULTS

5.1 Fitting the Merton Model

5.1.1 Role of the Merton model

Application of the Hsia approach is reliant on the Merton model having first been fitted satisfactorily. Hence tests of the Hsia approach are joint tests of the Merton model and the Hsia approach. It is therefore necessary to consider any issues arising in the fitting of the Merton model before turning to an examination of the Hsia approach itself.

5.1.2 Descriptive Statistics – The Sample

Descriptive statistics for the firm-years for which the Merton model was fitted to the sample data, showing means by credit rating, are set out in Table 2.

Table 2
Descriptive Statistics – Sample

Moody's Rating	Number of Observations (Firm-years)	Size (log $m, Dec year *t-1*)	Gearing B/(S+B)	Margin (% p.a.)	Term (years)
Aaa	110	10.06	13.2%	0.47%	13.9
Aa1	57	8.67	7.8%	0.62%	12.9
Aa2	184	9.06	10.8%	0.68%	12.7
Aa3	188	8.45	14.9%	0.74%	12.8
A1	256	8.11	17.0%	0.85%	12.6
A2	477	8.14	18.7%	0.87%	12.9
A3	334	7.75	21.1%	0.92%	13.0
Baa1	301	7.52	23.5%	1.09%	13.1
Baa2	373	7.34	27.9%	1.22%	12.7
Baa3	288	7.09	31.9%	1.33%	12.8
Ba1	202	6.58	35.6%	1.99%	11.6
Ba2	241	6.35	39.1%	2.22%	11.5
Ba3	357	5.69	43.5%	2.58%	10.9
B1	422	5.28	47.8%	3.35%	10.1
B2	141	4.86	57.6%	3.82%	9.8
B3	56	5.01	51.4%	4.04%	9.7
Caa1	24	4.22	62.0%	6.45%	7.9
Caa2	4	3.96	96.8%	6.55%	8.0
Caa3	4	2.65	79.4%	8.50%	6.8
Totals/Means	**4,019**	**7.20**	**29.7%**	**1.67%**	**12.1**

Firms were selected from Compustat with a known credit rating and balance sheet data available at any time between January 1986 and December 1998. Financial and utility companies were excluded, as were any firms with convertible debt, preferred stock or book value of interest bearing debt less than 1% of book value of interest bearing debt plus market value of equity. Firms also had to have market value of equity available from Compustat and stock return data available from Datastream.

As might be expected firms with lower credit ratings tend to be smaller and more highly geared. The yield spreads for the firm-years in the sample increase as credit rating declines. The declining term with declining credit rating simply reflects the inverse relationship of the former with the cost of debt under the Hsia approach.

5.1.3 Descriptive Statistics – Fitting the Merton Model

Table 3 sets out descriptive data for firm-year means, by credit rating, from fitting the Merton model.

Table 3
Descriptive Statistics – Fitted Merton Model

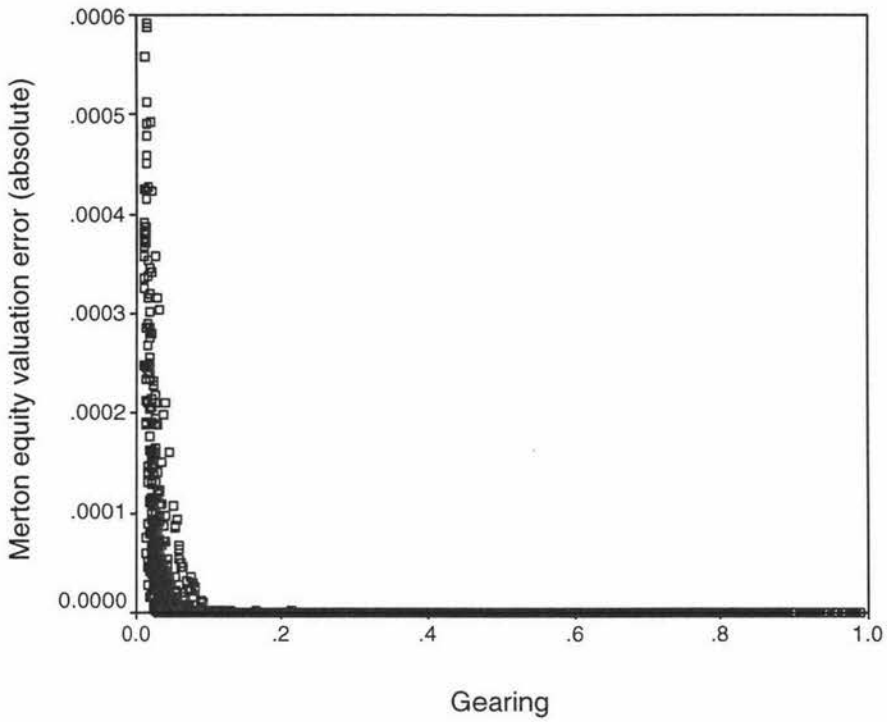
Moody's Rating	Number of Observations (Firm-years)	Merton Fitting Error (% Equity Value)	Implied /Historical Equity Volatility	Fitted Asset Volatility (% p.a.)
Aaa	110	0.0066%	1.89	36.6%
Aa1	57	0.0087%	1.77	44.1%
Aa2	184	0.0034%	1.86	40.5%
Aa3	188	0.0020%	1.75	38.1%
A1	256	0.0019%	1.73	38.0%
A2	477	0.0007%	1.58	35.2%
A3	334	0.0005%	1.46	34.3%
Baa1	301	0.0005%	1.48	34.2%
Baa2	373	0.0004%	1.41	32.8%
Baa3	288	0.0004%	1.31	31.5%
Ba1	202	0.0002%	1.43	34.1%
Ba2	241	0.0002%	1.18	33.4%
Ba3	357	0.0002%	1.14	33.5%
B1	422	0.0001%	1.17	35.1%
B2	141	0.0001%	1.00	31.2%
B3	56	0.0002%	1.04	36.7%
Caa1	24	0.0000%	1.14	35.9%
Caa2	4	0.0000%	1.00	14.7%
Caa3	4	0.0000%	1.07	29.6%
Total/Means	4,019	0.0010%	1.44	34.8%

The Merton model was fitted to the sample firms, by solving for asset volatility as the unknown. The fitting error is the absolute error between the fitted value of the firm's equity and the actual value of equity, after the fitting algorithm was terminated, at a maximum of 500 iterations. Implied equity volatility is calculated from estimated asset volatility, as per Cox and Rubinstein (1985, p. 210). The historical volatility of stock returns (i.e. equity) is measured over the preceding 24 to 60 months using monthly returns calculated from each stock's Datastream Total Return Index.

5.1.3.1 Equity Valuation Errors

The algorithm used to fit the Merton model was set to terminate after 500 iterations, if a solution had not been found. As can be seen from the error percentage in the second column of figures in Table 3, the algorithm had more difficulty in finding an exact solution within the prescribed number of iterations for firms with higher credit ratings. The figure in this column is the absolute percentage amount by which the Merton model value for equity differed from the actual market value at the point the algorithm was terminated. Although the resulting errors in valuing firms' equity, as per equation (21), are not material (the maximum error was 0.059%) it may be an indicator of problems in fitting the Merton model to firms of higher credit quality – which is correlated with lower borrowing margins and lower financial leverage. Figure 5 illustrates the relationship between gearing (=B/[B+S]) and equity valuation error for the sample firms:

Figure 5
Merton Model – Equity Valuation Errors



5.1.3.2 Relationship Between Implied and Observed Equity Volatility

The relationship between the volatility of the underlying asset, in this case the firm's assets, σ_V, and the option over those assets, in this case the firm's equity, σ_S, is shown by Cox and Rubinstein (1985, p.210) to be:

$$\sigma_S = \sigma_V \frac{V}{S} N(d_1) \tag{25}$$

Hence the values estimated for σ_V in fitting the Merton model can be converted to estimated values for σ_S, which in turn can be compared with actual values for σ_S as a broad indication of the goodness of fit of the Merton model. The third column of figures in Table 3 shows the ratio of the equity volatility implied from fitting the Merton model to the historical observed equity volatility (where this was available, using 24 to 60 months of

stock returns). Consistent with other empirical applications of the Merton model it is apparent that the volatility input required to fit the model is higher than is supported by the direct market evidence, on average one and a half times higher. The need to use an excessive volatility input to fit the model is more pronounced the higher the credit rating.

Figure 6 shows the relative equity volatility ratio against gearing (=B/[B+S]):

Figure 6
Merton Model – Implied/Historical Equity Volatility

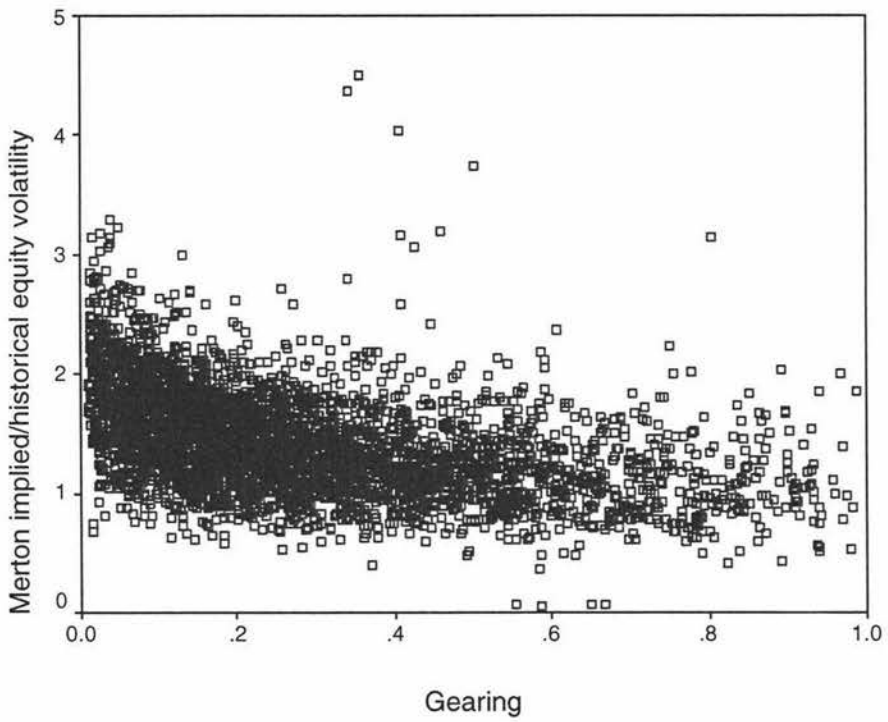


Figure 6 suggests a weak relationship between the extent of volatility over-estimation required to fit the Merton model and firms' gearing; the level of overestimation is more pronounced for firms with lower gearing. This is further evidence that it may be problematic forcing the Merton model to fit firms with high credit quality/low gearing.

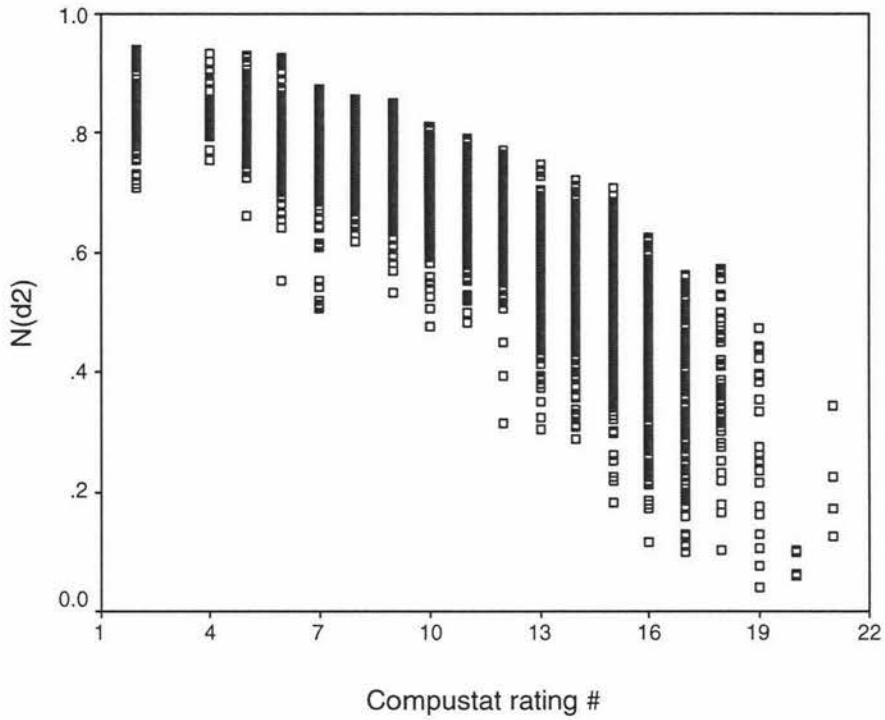
5.1.3.3 *Fitted Asset Volatility*

No obvious pattern is evident from Table 3 in the mean fitted asset volatility by rating, although the highest rating groups have somewhat higher asset volatilities. It is not clear if this is indicative of problems forcing the Merton model to fit these firms, or whether there is in fact a pattern of firms with high underlying asset risk adopting conservative gearing and thus perhaps attaining higher credit ratings.

5.1.4 *Risk Neutral Probability of Default*

Under the Merton model the value of $N(-d_2)$, or equivalently $1-N(d_2)$, represents the risk neutral probability that the firm will default. Hence a plot of $N(d_2)$ against credit rating, as shown in Figure 7, should provide a broad indication of whether or not the default probabilities from the fitted Merton model are consistent with the increasing default probability associated with a decreasing credit rating.

Figure 7
Merton Model – Risk Neutral Default Probabilities



It can be seen from Figure 7 that the measure of default probability from the Merton model increases as credit rating declines. This provides a degree of comfort that, at least in a relative sense, the fitted Merton model is capturing the greater credit risk of firms with lower credit ratings.

5.1.5 Summary on Fitting the Merton Model

In summary the specification of the Merton model, based on yield spread, and the algorithm used to solve for asset volatility as the unknown were successfully applied to fit the Merton model to all firms in the sample. However, examination of the (minor) pricing errors arising on fitting the model and of the relativity between implied and historical equity volatility raises concerns that the level of volatility input required to fit the Merton model may be unrealistically high, particularly for firms of higher credit quality/low gearing.

Errors in estimating firms' asset volatility, to fit the Merton model, will affect the calculation of expected excess returns under the Hsia approach. However, the sign of the first derivative of Hsia-based expected excess return with respect to asset volatility can be either positive or negative, depending on the values of the inputs used to calculate $N(d_1)$. Experimenting with illustrative data (not shown) reveals that the Hsia-based expected excess return can initially fall as asset volatility is overstated, before then rising to levels above the true estimate. This means that errors in the Merton model asset volatility estimates will introduce errors to the Hsia-based expected excess return estimates, which are likely to appear to some extent as random noise, but which may also introduce a systematic bias.

For example, if firms with low leverage have significantly overstated asset volatilities then they may also have overstated Hsia-based expected excess returns. Firms with medium leverage may have slightly overstated asset volatilities and hence understated Hsia-based expected excess returns. While firms with high leverage may have reasonable asset volatility estimates and hence reasonable Hsia-based expected excess returns estimates. Under such circumstances, and assuming that actual and expected stock returns are greater for more "risky" firms (e.g. more highly leveraged), a regression of expected excess returns against actual excess returns may have little power over the full sample. If the sample is split in half, on the basis of an appropriate risk measure (perhaps leverage) then for the low risk half of the sample there may be a negative slope between actual and Hsia-based expected excess returns, while the high risk half may show an exaggerated positive slope.

5.2 Applying the Hsia Approach

5.2.1 Descriptive Statistics

Table 4 compares the output from the Hsia approach, the expected excess return for stocks, with other asset pricing variables. Descriptive data is presented for firm-year means, by credit rating.

Table 4
Descriptive Statistics – Hsia Approach

Moody's Rating	Number of Observations (Firm-years)	Hsia-based expected excess return (% p.a.)	Beta	Size (log $m, Dec year *t-1*)	Book-to-market (Dec year *t-1*)
Aaa	110	5.7%	0.911	10.060	0.330
Aa1	57	6.9%	1.027	8.671	0.436
Aa2	184	7.0%	1.016	9.058	0.381
Aa3	188	7.0%	1.052	8.454	0.464
A1	256	7.4%	1.059	8.105	0.419
A2	477	7.0%	1.090	8.136	0.491
A3	334	7.1%	1.084	7.752	0.559
Baa1	301	7.5%	1.105	7.517	0.574
Baa2	373	7.9%	1.086	7.340	0.635
Baa3	288	8.1%	1.132	7.085	0.615
Ba1	202	10.4%	1.153	6.576	0.664
Ba2	241	11.0%	1.245	6.352	0.661
Ba3	357	12.3%	1.285	5.686	0.688
B1	422	15.0%	1.265	5.283	0.756
B2	141	17.2%	1.328	4.856	0.893
B3	56	17.8%	1.353	5.008	0.688
Caa1	24	28.7%	1.249	4.217	3.779
Caa2	4	41.9%	0.790	3.960	1.896
Caa3	4	35.0%	1.124	2.652	1.890
Total/Means	**4,019**	**9.6%**	**1.133**	**7.202**	**0.595**

Hsia-based expected excess returns are estimated at June in year *t* using book value of interest bearing debt from the fiscal year ended in or prior to December in year *t-1*, and the market value of equity, the estimated duration of the firm's interest bearing debt and the estimated margin on the firm's debt as at June in year *t*. Beta is computed using the Fama and MacBeth (1973) methodology, except that full post ranking betas are calculated for each beta (decile) portfolio. Based on sorting on pre-ranking betas firms are allocated a post ranking beta as at June in year *t*. Size and book-to-market are measured as at December in year *t-1*, as per Fama and French (1992).

From fitting the Merton model and then applying the Hsia approach the resulting Hsia-based excess return estimates are seen to increase as credit rating declines. However, as credit rating declines beta also increases, size declines and the book-to-market ratio increases. This suggests that if excess stock returns really do increase with declining firm credit quality then the Hsia approach, CAPM and the Fama-French three factor model may all have some ability to explain the variation in stock returns.

The Pearson correlations between these four asset pricing variables and credit rating (using the Compustat credit rating # as a nominal variable) are shown in Table 5.

Table 5
Correlation of Credit Rating and Asset Pricing Variables

	Hsia-based expected excess return	Beta	Size	Book-to-market
Compustat rating #	0.695	0.326	-0.755	0.217
Hsia-based expected excess return		0.280	-0.627	0.390
Beta			-0.269	0.099
Size				-0.342

Compustat rating # is a numeric value representing a firm's S&P credit rating. Hsia-based expected excess returns are estimated at June in year *t* using book value of interest bearing debt from the fiscal year ended in or prior to December in year *t-1*, and the market value of equity, the estimated duration of the firm's interest bearing debt and the estimated margin on the firm's debt as at June in year *t*. Beta is computed using the Fama and MacBeth (1973) methodology, except that full post ranking betas are calculated for each beta (decile) portfolio. Based on sorting on pre-ranking betas firms are allocated a post ranking beta as at June in year *t*. Size and book-to-market are measured as at December in year *t-1*, as per Fama and French (1992).

All pair-wise correlations are significant at the 0.01 level. The Hsia-based expected excess returns and size variables have high correlation coefficients with Compustat rating # and with each other.

5.2.2 Regression Analysis – Full Sample

Realised monthly excess stock returns (the dependent variable), from July in year *t* through June in year *t+1*, are regressed against the Hsia-based expected excess return estimates (the independent variable), estimated in June in year *t*. Realised monthly excess stock returns, over the same period, are also regressed against beta estimates and the other two Fama-French factors, size and book-to-market. The regression equations are run for each month, then the monthly coefficients are averaged (as per Fama and French, 1992). As per Fama and French 1992, the t-statistic is the mean of the monthly intercept or slope coefficient, divided by its time series standard error (which in turn is the standard deviation of the monthly time series of coefficients divided by the square root of the number of months). The mean regression coefficients, t-statistics and the mean of the monthly regression R^2 are presented in Table 6.

Table 6
Regression Results – Hsia Approach, CAPM and Fama-French Factors

Mean number of firm observations per month	Constant	Hsia-based expected excess return	Beta	Size	Book-to-market	Mean monthly R^2
298	0.003	0.349				0.031
	(0.652)	(0.713)				
274	0.002		0.003			0.018
	(0.391)		(0.774)			
275	0.006			0.000		0.027
	(0.729)			(-0.056)		
258	0.003		0.002	0.000		0.044
	(0.323)		(0.555)	(0.053)		
261	0.005				0.001	0.024
	(1.213)				(0.346)	
261	-0.002			0.001	0.003	0.046
	(-0.219)			(0.983)	(1.006)	
246	0.004		0.001		0.001	0.043
	(0.839)		(0.146)		(0.424)	
246	-0.006		0.002	0.001	0.003	0.063
	(-0.680)		(0.500)	(1.226)	(1.152)	

Hsia-based expected excess returns are estimated at June in year *t* using book value of interest bearing debt from the fiscal year ended in or prior to December in year *t-1*, and the market value of equity, the estimated duration of the firm's interest bearing debt and the estimated margin on the firm's debt as at June in year *t*. Beta is computed using the Fama and MacBeth (1973) methodology, except that full post ranking betas are calculated for each beta (decile) portfolio. Based on sorting on pre-ranking betas firms are allocated a post ranking beta as at June in year *t*. Size and book-to-market are measured as at December in year *t-1*, as per Fama and French (1992).

Realised monthly excess stock returns are the dependent variable, from July in year *t* through June in year *t+1*, these are regressed against the Hsia-based expected excess return estimates, beta, firm size and book-to-market variables, estimated in June in year *t*. The regression equations are run for each month, then the monthly coefficients are averaged (as per Fama and French, 1992). In total the regression equations are run for 156 months, from July 1987 through June 2000. As per Fama and French 1992, the t-statistic is the mean of the monthly regression coefficient, divided by its time series standard error (which in turn is the standard deviation of the monthly time series of coefficients divided by the square root of the number of months). Mean monthly R^2 is the mean of the R^2 from the month-by-month regression equations.

The Hsia-based expected excess return variable has the expected positive slope coefficient, but it is not statistically significant at the 0.05 level. Across the full sample the Hsia approach, based on fitting the underlying Merton

model, has little ability to explain the variation in realised stock returns. None of the regression equations have R^2 in excess of 0.01.

Beta has the expected positive slope in all of the models tested, but none of the coefficients is statistically significant at the 0.05 level. The Hsia-based expected excess returns have a similar t-statistic to beta, but its regression equations have a higher mean monthly R^2.

The size and book-to-market variables fare better when both are present in the regression model, having higher t-statistics, but are still not statistically significant at the 0.05 level. Moreover, the sign of the size coefficient is positive in all of the models containing one or more additional independent variables, which is contrary to the findings of Fama and French (1992). Further, unlike Fama and French (1992), neither size nor book-to-market is statistically significant when it is the only independent variable. These differences from Fama and French's findings are likely to reflect the different time period used[16] and the different criteria for selecting firms[17] to be included in the analysis. Over the period of this study (July 1987 through June 2000) large capitalisation stocks performed better than small capitalisation stocks (as measured by the Wilshire large cap 750 index compared with the other Wilshire indexes, for smaller capitalisation stocks).

In terms of the means of the monthly regression R^2, the Fama-French model has greater explanatory power than the Hsia approach, which in turn has

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[16] Fama and French (1992) examine returns for the period July 1963 through December 1990. This study examines returns for the period July 1987 through June 2000.

[17] Fama and French (1992) select US listed firms from the intersection of the Compustat (balance sheet variables) and CRSP (market-based variables) databases; financial firms and firms with insufficient stock return data are excluded. This study selects North American firms from the intersection of the Compustat (credit rating, market value of equity and balance sheet variables) and Datastream (stock returns) databases. This study uses more restrictive screening criteria; financial and utility firms are excluded, firms must have a credit rating, must have at least 1% of interest bearing debt in their capital structure and no convertible debt or preferred stock on issue. Fama and French (1992, p.439, Table III) have an average of 2,267 firms in their monthly regressions, this study has an average of 298.

greater explanatory power than the CAPM. However, none of the models is found to be statistically significant at the 0.05 level.

5.2.3 Regression Analysis – Split Sample

Given the issues which arose in fitting the Merton model to the data and the postulated effect this may have on regression slopes when testing the Hsia approach, it was decided to split the sample into halves, based on a range of different variables which can primarily be regarded as potential measures of how well suited the Merton model is to firms most/least associated with that variable. It is postulated that in general the more "option-like" the firm is the more applicable the Merton model will be. The variables tested and their predicted effect on better fitting the Merton model, and hence improving the explanatory power of the Hsia approach are set out in Table 7.

Table 7
Criteria for Splitting Sample

Sorting variable	Sort criterion expected to improve fit of Merton model/Hsia approach
Rating	Lower
Size (log $m)	Smaller
Book-to-market	Higher
Beta	Higher
Gearing	Higher
Implied asset volatility	?
Historical equity volatility	?
Implied equity volatility	?
Implied/historical equity volatility	Closer to 1.0
$N(d_1)$	Lower
$N(d_2)$	Lower
Proportion of short term debt	Lower
Margin	Higher

The coefficients, t-statistics and mean monthly R^2 from regressing realised excess stock returns (dependent variable) against the Hsia-based expected

excess returns (independent variable) for the split samples are presented below in Table 8.

Table 8
Regression Results – Hsia Approach with Split Sample

Sorted by	Criterion	Mean Number of Firm Observations per Month	Constant		Hsia-based expected excess return		Mean Monthly R^2
			Coefficient	t-statistic	Coefficient	t-statistic	
Full sample		298	0.003	(0.652)	0.349	(0.713)	0.031
Rating	Investment grade	193	0.003	(0.479)	0.274	(0.292)	0.012
	Non-investment grade	105	-0.001	(-0.130)	0.647	(0.826)	0.038
Size (log$m)	Small	138	0.000	(-0.026)	0.630	(1.127)	0.036
	Large	138	0.008	(1.250)	-0.231	(0.826)	0.026
Book-to-market	Low	131	0.004	(0.792)	0.163	(0.278)	0.039
	High	131	0.006	(1.035)	-0.026	(-0.047)	0.040
Beta	Low	133	0.006	(0.968)	0.046	(0.063)	0.055
	High	142	0.003	(0.505)	0.380	(0.720)	0.033
Gearing	Low	149	0.004	(0.774)	0.372	(0.649)	0.030
	High	149	0.001	(0.189)	0.501	(0.887)	0.040
Implied asset volatility	Low	149	0.004	(0.719)	0.234	(0.390)	0.051
	High	149	0.002	(0.459)	0.462	(0.935)	0.026
Historical equity volatility	Low	137	0.011	(2.035) *	-0.825	(-1.332)	0.017
	High	137	0.000	(0.065)	0.623	(1.091)	0.034
Implied equity volatility	Low	149	0.028	(2.698) **	-3.464	(-2.109) *	0.029
	High	149	0.001	(0.088)	0.583	(0.995)	0.036
Implied / historical equity volatility	Low	137	0.002	(0.339)	0.477	(0.837)	0.036
	High	137	0.006	(1.085)	0.009	(0.014)	0.044
$N(d_1)$	Low	149	-0.001	(-0.121)	0.691	(1.236)	0.037
	High	149	0.007	(1.423)	-0.151	(-0.229)	0.033
$N(d_2)$	Low	149	-0.001	(-0.178)	0.644	(1.166)	0.032
	High	149	0.005	(0.644)	0.162	(0.163)	0.016
Proportion of short term debt	Low	149	0.000	(-0.080)	0.665	(1.100)	0.045
	High	149	0.006	(1.344)	0.037	(0.071)	0.037
Margin	Low	149	0.014	(2.079) *	-1.255	(-1.272)	0.017
	High	149	-0.004	(-0.646)	0.908	(1.458)	0.035

** Significant at the 0.05 level.*
*** Significant at the 0.01 level.*

Table 8 (continued)

The full sample is split into two equally sized halves, based on the specified sort criterion. Except in the case of credit rating, where the breakpoint is set at investment grade/non-investment grade.
Hsia-based expected excess returns are estimated at June in year *t* using book value of interest bearing debt from the fiscal year ended in or prior to December in year *t-1*, and the market value of equity, the estimated duration of the firm's interest bearing debt and the estimated margin on the firm's debt as at June in year *t*.
Realised monthly excess stock returns are the dependent variable, from July in year *t* through June in year *t+1*, these are regressed against the Hsia-based expected excess return estimates, as estimated in June in year *t*. The regression equations are run for each month, then the monthly coefficients are averaged (as per Fama and French, 1992). In total the regression equations are run for 156 months, from July 1987 through June 2000. As per Fama and French 1992, the t-statistic is the mean of the monthly regression coefficient, divided by its time series standard error (which in turn is the standard deviation of the monthly time series of coefficients divided by the square root of the number of months). Mean monthly R^2 is the mean of the R^2 from the month-by-month regression equations.

It can be seen that once the full sample is split in half, to potentially be more or less "option-like"[18], some of the coefficients for the Hsia-based expected excess return become more statistically significant (i.e. have higher t-statistics). Positive slopes are associated with the more "option-like" half of the sample, while the least "option-like" half of the sample tends to have negative slopes on the Hsia variable. A negative slope on the Hsia variable could be interpreted as evidence that the Hsia approach works in the opposite way to that predicted (i.e. firms with the highest Hsia-based expected returns actually have the lowest returns and vice versa); it could also be interpreted as an indication of problems with fitting the Merton model and/or applying the Hsia approach.

Sorting the sample on the basis of a non-investment grade bond credit rating, small size, high gearing, high implied asset volatility, high historical equity volatility, high implied equity volatility, low implied/historical equity volatility, low $N(d_1)$ value, low $N(d_2)$ value, low proportion of short term debt and high borrowing margin all result in higher loadings on the Hsia-based

[18] In general terms more "option-like" firms have higher gearing and/or greater risk and hence a higher probability of default.

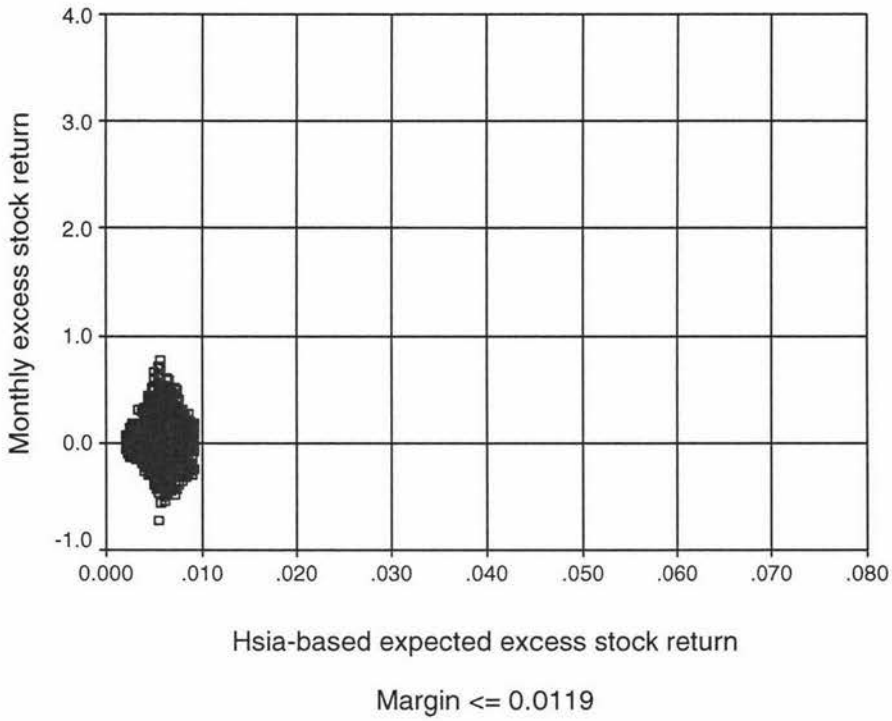
expected excess return and higher t-statistics, but still not of statistical significance at the 0.05 level.

The low implied/historical equity volatility sub-sample had a cut-off point of 1.4 times, so is still likely to contain a lot of "noise" from forcing the Merton model to fit. Thus while this sub-sample has a slightly increased positive slope loading and t-statistic with respect to the Hsia variable, the improvement on the full sample is only minor.

Sorting on book-to-market and beta did not yield any improvement in explanatory power for the Hsia-based expected excess returns. The split sample with the highest t-statistic is the high borrowing margin sub-sample, for which the t-statistic on the Hsia variable (1.458) is only statistically significant at the 14.7% level.

Figures 8 and 9, drawn to the same scale, illustrate the effect of splitting the full sample into two and then comparing realised excess returns with Hsia-based expected excess returns (all months are pooled). The split has been done on the basis of borrowing margin, as assigned to firms by their respective credit rating. The first plot, Figure 8, is for firms with low borrowing margins.

Figure 8
Hsia-based Expected v. Actual Excess Monthly Stock Returns, Pooled Data, Low Borrowing Margin



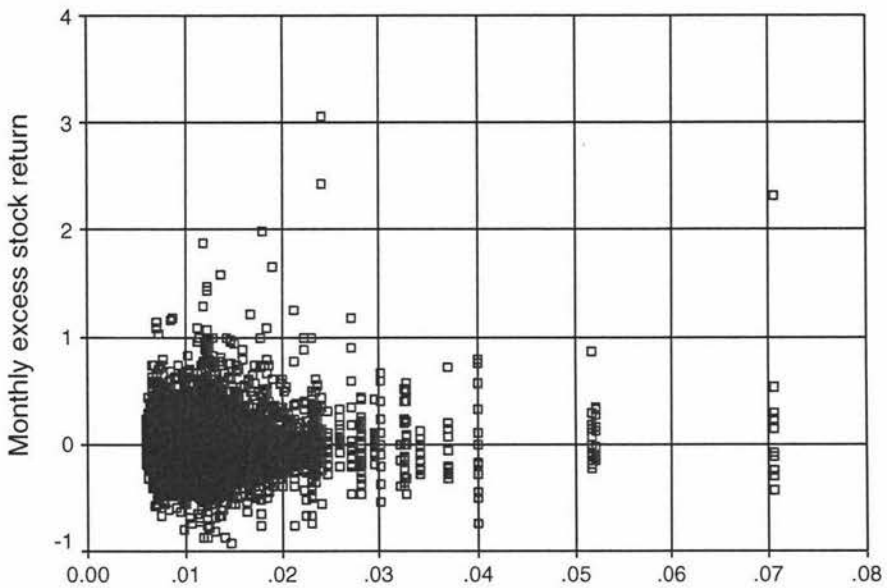
It can be seen that there is very little variation between firms' expected excess returns for the low borrowing margin sub-sample. Nor is the variation between firms' realised returns particularly large. Within this sub-sample it would appear that any errors in fitting the Merton model (e.g. by way of an excessive asset volatility input) could readily mask any power the Hsia approach might have to explain expected returns for this group of firms.

It may also be that the any systematic overstatement of the asset volatility input may cause bias in regression tests of the Hsia approach. Other things being equal, if firms with lower borrowing margins also have lower true Hsia-based expected excess returns, but require excessively high implied asset volatilities to fit the Merton model, then their estimated Hsia-based expected excess returns may be overstated. If this were so, a regression to test the

power of the Hsia approach on this sub-ample may find a negative relationship between realised excess returns and Hsia-based expected excess returns.

Figure 9 presents the plot of realised excess returns against Hsia-based expected excess returns for firms with high borrowing margins.

Figure 9
Hsia-based Expected v. Actual Excess Monthly Stock Returns, Pooled Data, High Borrowing Margin



It can be seen that there is considerably more variation between firms' realised excess returns and also their expected excess returns for the high borrowing margin sub-sample. This suggests that testing the Hsia approach on such a sub-sample may be less affected by noise in the data.

From examining Figure 9 it appears that the regression results for this sub-sample may be influenced by a small number of outlier observations. To

examine this possibility the high borrowing sub-sample was trimmed to exclude all realised monthly returns equal to or greater than 1.5 (i.e. 150%) and all Hsia-based expected excess returns equal to or greater than 0.04. This reduced the firm-month sub-sample size from 23,274 to 23,225, a reduction of 49 observations. The month-by-month regression was then rerun on the trimmed sub-sample. The results are as follows:

Table 9
Regression Results – Hsia Approach, Trimmed High Borrowing Margin Sub-sample

Sorted by	Criteria	Mean Number of Firm Observations per Month	Constant		Hsia-based expected excess return		Mean Monthly R^2
			Coefficient	t-statistic	Coefficient	t-statistic	
Margin, trimmed sample	High	149	0.001	(0.099)	0.375	(0.665)	0.028

* *Significant at the 0.05 level.*
** *Significant at the 0.01 level.*

The sub-sample is the half of the full sample with the highest borrowing margins. The sub-sample is trimmed to exclude all realised monthly returns equal to or greater than 1.5 (i.e. 150%) and all monthly Hsia-based expected excess returns equal to or greater than 0.04.
Hsia-based expected excess returns are estimated at June in year *t* using book value of interest bearing debt from the fiscal year ended in or prior to December in year *t-1*, and the market value of equity, the estimated duration of the firm's interest bearing debt and the estimated margin on the firm's debt as at June in year *t*.
Realised monthly excess stock returns are the dependent variable, from July in year *t* through June in year *t+1*, these are regressed against the Hsia-based expected excess return estimates, as estimated in June in year *t*. The regression equations are run for each month, then the monthly coefficients are averaged (as per Fama and French, 1992). In total the regression equations are run for 156 months, from July 1987 through June 2000. As per Fama and French 1992, the t-statistic is the mean of the monthly regression coefficient, divided by its time series standard error (which in turn is the standard deviation of the monthly time series of coefficients divided by the square root of the number of months). Mean monthly R^2 is the mean of the R^2 from the month-by-month regression equations.

Exclusion of extreme observations from the high borrowing margin sub-sample reduces the slope on the Hsia-based expected excess return and also reduces the t-statistic – to levels comparable to those for the full sample. This illustrates that the improved power of the untrimmed sub-sample regression is reliant on a small number of "extreme" observations. While these observations might be excluded on statistical grounds, as "anomalies", it can

also be argued that fat-tailed returns distributions are a feature of the stock market and thus "extreme" observations should be left in the sample.

5.2.4 Regression Analysis – By Calendar Month

To examine the possibility that the Hsia approach may rely on current information, in particular the market value of equity and the cost of debt (as estimated in this study via credit ratings), the full sample month-by-month regressions testing the Hsia approach were tabulated on a calendar month basis. If the Hsia approach is heavily reliant on the most current data it might be expected that the most statistically significant positive regression coefficient would be observed in July in year *t*, with explanatory power decaying through to June in year *t+1*. Table 10, below, presents the results of the calendar month regressions.

Table 10
Regression Results – Hsia Approach, by Calendar Month

Calendar month	Mean number of firm observations per month	Constant		Hsia-based expected excess return		Mean monthly R^2
		Coefficient	t-statistic	Coefficient	t-statistic	
July	301	0.013	(0.771)	-0.614	(-0.673)	0.015
August	301	-0.010	(-0.697)	-1.068	(-0.838)	0.026
September	300	-0.008	(-0.674)	0.923	(0.781)	0.022
October	300	0.014	(0.720)	-5.825	(-4.172) **	0.048
November	299	0.016	(1.288)	-1.555	(-1.110)	0.024
December	299	0.048	(4.120) **	-2.572	(-3.044) *	0.015
January	298	-0.046	(-2.607) *	7.182	(3.768) **	0.078
February	298	-0.001	(-0.067)	2.212	(1.441)	0.023
March	297	0.008	(0.390)	1.087	(0.601)	0.023
April	297	0.006	(0.388)	1.936	(0.772)	0.056
May	296	0.009	(0.727)	1.522	(1.010)	0.025
June	295	-0.013	(-0.800)	0.959	(0.705)	0.017

* *Significant at the 0.05 level.*
** *Significant at the 0.01 level.*

Hsia-based expected excess returns are estimated at June in year *t* using book value of interest bearing debt from the fiscal year ended in or prior to December in year *t-1*, and the market value of equity, the estimated duration of the firm's interest bearing debt and the estimated margin on the firm's debt as at June in year *t*.
Realised monthly excess stock returns are the dependent variable, from July in year *t* through June in year *t+1*, these are regressed against the Hsia-based expected excess return estimates, as estimated in June in year *t*. The regression equations are run for each month, then the monthly coefficients are averaged (as per Fama and French, 1992). In total the regression equations are run for 156 months, from July 1987 through June 2000. As per Fama and French 1992, the t-statistic is the mean of the (calendar) monthly regression coefficient, divided by its time series standard error (which in turn is the standard deviation of the monthly time series of coefficients divided by the square root of the number of months). Mean monthly R^2 is the mean of the R^2 from the month-by-month regression equations.

The regression results do not support the proposition that the Hsia approach works best with most current information, then decays in power on a month-by-month basis. There are statistically significant negative loadings on the Hsia variable in October and December. There is then a statistically significant positive loading on the Hsia variable in the month of January. The October regression was also run excluding the share market "crash" month of October 1987, this did not change the sign or statistical significance (at the

0.01 level) of the regression coefficient on the Hsia variable. Interestingly the month with the strongest positive loading on the Hsia variable and one of the highest levels of statistical significance is January. Is the Hsia approach able to explain the "January effect"?

Chapter 6

6 CONCLUSIONS

6.1 Summary

6.1.1 Research Undertaken

This research has tested the application of an option pricing model based approach to estimate expected excess stock returns, the Hsia approach. The underlying option-theoretic model of the firm, the Merton model, and the Hsia equation for the cost of equity, equation (11), are specified relative to the firm's borrowing margin. Firms' borrowing margins are estimated by reference to their credit rating and the credit spread implicit in the yield on corporate bond indexes of the same credit rating. The Merton model is then fitted, largely using the approach suggested by Hsia (1991), and Hsia-based expected excess returns are then estimated. Tests of the Hsia approach are thus joint tests of the Merton model and of the Hsia approach.

The Merton model is successfully fitted in its basic form by solving for firm asset volatility and, consistent with prior studies, the implied volatility for firms' assets is found, on average, to be higher than that expected from examining historical equity volatility. There is also evidence that this problem, of needing to "over estimate" volatility, is more pronounced the less "option-like" the firm is, e.g. for firms with low leverage.

Errors in estimating firms' true asset volatility will affect the ability of the Hsia approach to explain the variation in realised stock returns. It is postulated that there may be a systematic bias introduced to the estimation of the Hsia-

based expected excess returns as a result of larger "over estimates" of firm asset volatility being required the less option-like a firm is.

6.1.2 Research Findings

Month-by-month regression tests are done, with monthly realised excess stock returns as the dependent variable. Across the full sample of 46,553 firm-months the Hsia-based expected excess returns are found to be only weakly, positively associated with realised excess returns, and not of statistical significance at the 0.05 level. For the sample firms, over the sample period, the CAPM is tested and beta is not found to be statistically significant at the 0.05 level.

Size and book-to-market variables have somewhat more explanatory power than the Hsia approach or beta, when both are present in the regression model, but are still not of statistical significance at the 0.05 level. Moreover, upon inclusion of beta and/or book-to-market in the regression model the sign of the size coefficient is positive, which is contrary to the findings of Fama and French (1992). Further, unlike Fama and French (1992), neither size nor book-to-market is statistically significant (at the 0.05 level) in any of the models tested. These differences from Fama and French's findings are likely to reflect the shorter time period used in this study[19] and the different (more restrictive) criteria for selecting firms to be included in the analysis[20].

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[19] Fama and French (1992) examine returns for the period July 1963 through December 1990. This study examines returns for the period July 1987 through June 2000.

[20] Fama and French (1992) select US listed firms from the intersection of the Compustat (balance sheet variables) and CRSP (market-based variables) databases; financial firms and firms with insufficient stock return data are excluded. This study selects North American firms from the intersection of the Compustat (credit rating, market value of equity and balance sheet variables) and Datastream (stock returns) databases. This study uses more restrictive screening criteria; financial and utility firms are excluded, firms must have a credit rating, must have at least 1% of interest bearing debt in their capital structure and no convertible debt or preferred stock on issue. Fama and French (1992, p.439, Table III) have an average of 2,267 firms in their monthly regressions, this study has an average of 298.

When the sample is split in half on the basis of various option-like characteristics (such as higher gearing), the more option-like sub-sample is found to have a greater positive loading and higher t-statistic for the Hsia-based expected excess return variable. However, none of the slope coefficients is statistically significant at the 0.05 level. Moreover, the improved statistical power of the relationship is found to be driven by a relatively small number of extreme return observations.

6.2 Limitations

Limitations of this research are:

1. Reliance on the Merton model, which is based on several simplifying assumptions that are unlikely to true in practice.
2. Estimating firms' borrowing margins by reference to their credit rating and the credit spread implicit in the yield on corporate bond indexes of the same credit rating, when:
   a.) There is likely to be variation of individual firm borrowing margins within each rating category;
   b.) Firms' credit quality may change, but their rating is not updated immediately by the rating agencies; and
   c.) The bond indexes used include callable bonds, whose presence may mean the estimated credit spreads are affected by the value of call features.
3. The relatively short time period over which the sample was drawn from, by comparison with other asset pricing studies. However, use of a longer time period is more problematic in terms of data availability.

6.3 Contribution to the Body of Knowledge

This study has contributed to the body of knowledge by:

1. Establishing a formulation of the Hsia approach to estimating firm's expected excess returns on equity which does not require knowledge of the risk free rate of interest;
2. Confirming prior empirical findings regarding the need to use "excessive" volatility estimates to fit the Merton model;
3. Confirming the general ability of the Merton model to differentiate the credit risk of firms (as measured by their risk neutral probability of default);
4. Finding that the Hsia approach does not have any greater ability to estimate, ex ante, the cross-sectional variation in firms' realised stock returns than does the CAPM or the Fama-French three factor model (although with the data set used in this study none of the models was found to have statistically significant explanatory power); and
5. Finding that the Hsia approach has greater potential for application to more "option-like" firms.

The results of this study provide some ideas and possible directions for further research into applying the Hsia approach, some of which are discussed below.

6.4 Future Research

This research provides some tentative support for the Hsia approach, but does not provide a clear conclusion about its ability to explain the variation in realised excess stock returns. It is suspected that volatility estimation errors arising from fitting the Merton model, in its basic form, have introduced errors into the Hsia-based expected excess return estimates – possibly in a systematic manner. Future research on applying the Hsia approach should first attempt to improve on the fitting of the Merton model, in particular the implied firm asset volatility estimates. This might involve applying a more sophisticated variant of the Merton model or perhaps screening out firms that

are less option-like. It is not known if better fitting of the Merton model would strengthen the performance of the Hsia approach, but it is suspected that this might be the case.

In applying the Hsia approach itself it is thought that the main area to reduce potential sources of error would be to use firm specific borrowing margins, although such information is not readily available for most of the debt on issue, for a large number of companies. The other Hsia input which could be experimented with is the term of the firm's debt. Rather than using the duration of a perpetual bond, as advocated by Hsia (1991), the average duration of a firm's existing debt on issue (i.e. with known finite maturities) could be used.

The variables used in the regression models could be tested under different transformations. For example, realised stock returns could be measured on a logarithmic basis.

The time period over which the Hsia approach is estimated and tested could be lengthened, to reduce the standard error of the regression coefficients and to reduce the effect of any anomalous stock market periods (e.g. October 1987 crash). It would also be desirable to increase the number of firms in the sample at any one time.

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APPENDIX A

Merrill Lynch High Yield Master II Index

The MLHYM index comprises US corporate bonds with a Moody's or S&P rating (using Moody's notation) of Ba, B and Caa. Information in this index is used to "predict" credit spreads as at June 1987, 1988 and 1999, at which time the Lehman Brothers non-investment grade corporate bond indexes were not yet in existence.

Since the MLHYM index closely tracks[21] the Lehman Brothers B corporate bond index, it is used as a proxy for the Lehman Brothers B corporate bond index as at June 1987, 1988 and 1999. To apply the credit spread estimation methodology described above, the average life of the constituent bonds of the MLHYM index is assumed to be 10 years.

Information implicit in the MLHYM index is also used to estimate credit spreads for Ba and Caa bonds as at June 1987, 1988 and 1999. Regression analysis was undertaken to establish a relationship between the monthly credit spread of the MLHYM index and the credit spreads of the Lehman Brothers non-investment grade bond indexes, when overlapping data was available for these indexes (March 1990 through September 2000). Information contained in the Lehman Brothers investment grade indexes is also used in the regression, specifically the difference between the Aa and A credit spreads –

[21] As at October 1999 the Merrill Lynch High Yield Master II index comprised (by weight): - Ba 36.3%, B 54.0% and C 9.7%. Over the preceding five years the index correlations, as per Merrill Lynch, with each of its constituent rating groups was: - Ba 0.877, B 0.966, Caa 0.714. A regression of the end of month yield of the Merrill Lynch index against the yield of Lehman Brothers B corporate bond index

which is found to have explanatory power. The objective of this analysis is to extend the credit spreads which can be matched to the firm sample by "predicting" spreads for Ba, B and Caa rated firms for the period prior to March 1990, when the Lehman Brothers non-investment grade bond indexes commenced.

The final regression equations used are:

$$Ba^{Spread} = 0.95Baa^{Spread} + 1.55\left(Aa^{Spread} - A^{Spread}\right) + 0.18MLHYM^{Spread} \quad (R^2=0.78)$$

$$Caa^{Spread} = 0.30Baa^{Spread} - 20.47\left(Aa^{Spread} - A^{Spread}\right) + 2.71MLHYM^{Spread} \quad (R^2=0.61)$$

for the period March 1990 until September 2000, with the intercept set to zero, had a slope of 0.97 and R^2 of 0.88.