Three Essays on Corporate Debt, Capital Structure and Managerial Entrenchment

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To Xiaoying
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III
Abstract

This dissertation comprises three essays. In the first essay, I develop a contingent-claims model to investigate the impact of managerial entrenchment on corporate policies and security valuation. The model emphasizes the role that managerial agency issues play in determining both a firm's dividend payout and capital structure. I show quantitatively that self-interested managers' leverage choices deviate from those ex ante maximize firm values. The results suggest that dividend yields are negatively affected by both leverage ratios and managerial entrenchment. They provide implications for empirical research attempting to relate dividend policy to capital structure. In addition, the model offers a new framework to measure managerial entrenchment using observed leverage and dividend payout.

In the second essay, we use a set of structural models to evaluate the price of default protection for a sample of US corporations. In contrast to previous evidence from corporate bond data, CDS premia are not systematically underestimated. In fact, one of our studied models has little difficulty on average in predicting their level. For robustness, we perform the same exercise for bond spreads by the same issuers on the same trading date. As expected, bond spreads relative to the Treasury curve are systematically underestimated, consistent with their being driven by significant non-default components. This is not the case when the swap curve is used as a benchmark, suggesting that previously documented underestimation results may be sensitive to the choice of risk free rate.

In the third essay, we develop a valuation model that simultaneously captures credit risk and interest rate risk, and apply it to study the valuation
of putable corporate bonds. We ask what risks put features provide insurance against in practice - credit risk, liquidity risk or interest rate risk - and to what degree? We find that they reduce the components of all three risks in bond spreads. The most important, perhaps surprisingly is default or spread risk, followed by term structure risk. The reduction in the liquidity component is present but rather small.
Résumé

Ce traité comprend trois essais. Dans le premier essai, je développe un modèle de contrats contingents pour examiner l'impact de retranchement directorial sur les politiques financières d'une entreprise et l'évaluation des titres émis par celle-ci. Le modèle souligne le rôle des problèmes d'agence directoriaux dans la détermination de la politique de dividendes et la structure financière. Je montre quantitativement que le choix de levier effectué par les directeurs dévie de celui qui maximise la valeur de l'entreprise. Les résultats suggèrent que le taux de dividendes est négativement affecté par les proportions de levier et de retranchement directorial. Je fournis des implications empiriques sur le lien entre la politique de dividende et la structure financière.

Dans le deuxième essai, nous utilisons une série de modèles structuraux pour évaluer les prix de protection de défaut pour un échantillon de sociétés américaines. En contraste avec la plupart des travaux antérieurs sur les rendements d'obligations, les primes de CDS ne sont pas systématiquement sous-estimées. En fait, un de nos modèles étudiés a peu de difficulté à en moyenne prédire leur niveau.

Dans le troisième essai, nous développons un modèle d'évaluation qui capture simultanément le risque de crédit et le risque de taux d'intérêt. Nous l'appliquons pour étudier l'évaluation des obligations qui peuvent être revenues à l'émetteur à prix fixe. Nous demandons contre quels risques ces contrats fournissent de l'assurance dans la pratique - le risque de crédit, le risque de liquidité ou le risque de taux d'intérêt - et à quel degré? Nous trouvons qu'ils réduisent l'impact des trois risques. Le plus important est une diminu-
tion dans le risque de défaut, suivi par le risque de variations dans le taux sans risque. La réduction dans la composante de liquidité est présente mais plutôt petite.
Contributions of Authors

The first essay of this thesis was written entirely by Hao Wang.

The second essay is a joint collaboration between Hao Wang, Jan Ericsson and Joel Reneby. Jan Ericsson is an Associate Professor of Finance, Desautels Faculty of Management, McGill University. Joel Reneby is an Associate Professor of Finance, Stockholm School of Economics. Hao Wang performed all the data management and a substantial part of the data analyses that make up the chapter, and did part of the writing. Jan Ericsson and Joel Reneby developed the main research ideas behind the chapter and wrote the revisions of the chapter.

The third essay is a joint collaboration between Hao Wang, Jan Ericsson, and Redouane Elkamhi, PhD student of Finance, Desautels Faculty of Management, McGill University. Hao Wang, together with Redouane Elkamhi, performed data management, estimation and data analyses that make up the chapter, and wrote the chapter. Jan Ericsson helped to develop the main research ideas behind the chapter and with the revisions of the chapter.
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Chapter 1

Introduction


This thesis draws on the recent development of the structural form contingent claims models to study payout dynamics, capital structure and security valuation. The first essay develops a theoretical framework to examine how managerial entrenchment influences dividend payout policy and capital structure by bridging the contingent claims literature and the corporate agency literature. The other two essays are on the empirical side examining credit
risk, interest rate risk and liquidity risk using a variety of fixed income and credit derivative data.

Contingent claims models on the valuation of corporate securities have been used extensively to study capital structure choice. However, this literature has, by and large, ignored a central problem in corporate governance, which is the misalignment of the incentives of managers and shareholders\(^1\). The fact that shareholders rely on managers to implement financing decisions raises interesting questions: What influences self-interested managers' capital structure decisions? To what extent do their leverage choices deviate from those \textit{ex ante} optimize firm values? What are the implications for security values? It is important for the contingent claims literature to explore these questions in order to provide meaningful implications for empirical research valuating securities. However, little work has been done so far.

In the first essay, I develop a contingent claims model to investigate the impact of managerial entrenchment on corporate policies and security valuation. The model emphasizes the role that managerial agency issues play in determining both a firm's dividend payout and capital structure. Specifically, entrenched managers choose leverage not only to reduce the likelihood of bankruptcy but also to avoid a threat from shareholders to terminate their contract. Managers will assume the minimum amount of debt necessary and choose the minimum dividend payout rate to prevent the shareholders from exercising their threat to fire. I show quantitatively that self-interested managers' leverage choices deviate from those \textit{ex ante} maximize firm values. The results suggest that dividend yields are negatively affected by both leverage ratios and managerial entrenchment. They provide implications for empirical research attempting to relate dividend policy to capital structure. In addition,\(^1\)

the model offers a new framework to measure managerial entrenchment using firm leverage and dividend payout.

A widespread view amongst financial economists is that structural models of credit risk following Black & Scholes (1973) and Merton (1974), although theoretically appealing, underestimate the actual default risk discount on credit risky securities. Several studies from the 1980’s onwards document the models producing credit spreads lower than actual corporate bond spreads². A recent financial innovation, the credit default swap (CDS) permits the measurement of the default risk component of a corporate issuer in isolation. In addition, CDS are commonly thought to be less influenced by non-default factors. The CDS market thus provides an interesting alternative source of data to reassess the empirical performance of structural models that by construction only measure default risk.

In the second essay, we compare predicted levels of credit default swap (CDS) premia with their market counterparts for a selection of structural models. In contrast to what has previously found on corporate bond data, CDS premia are not systematically underestimated. In fact, one of our studied models has little difficulty on average in predicting their level.

For robustness, we also compare the models’ theoretical bond spreads to their market counterparts. CDS contracts are closely related to corporate bonds by an arbitrage argument. A package of a par floating rate corporate bond and protection bought with a CDS is a risk free investment. Given that a CDS contract requires no up front payment (i.e. it is unfunded), the comparison with the bond requires taking into account the funding rate of a bondholder. In practice, this implies that the relevant measure of the bond yield spread that is comparable to the CDS price is the spread to the swap curve. In contrast most previous empirical research on corporate bonds use

the Treasury curve as a benchmark. As a result we carry out our analysis using reference yield curves based both on Treasury yields and interest swap rates.

We use a simple building block approach to develop a pricing formula for credit default swaps (henceforth, CDS). The formula is applied in the framework of three distinct structural models: Leland (1994), Leland & Toft (1996) and Fan & Sundaresan (2000). By implementing multiple models, we hope to gauge the robustness of our results to specific model assumptions. We estimate the structural models using firm-specific balance sheet and market data on stock prices, and then compute the term structures of risk-adjusted default probabilities and the corresponding prices for corporate bonds and CDS for the same corporate issuer\(^3\). By using pairs of contemporaneous transactions and quotes for default swaps and a bond issued by the reference entity, we can compare the estimated bond yield spreads and CDS spreads with two separate sets of data.

Consistent with previous evidence, the models do systematically underpredict bond spreads when benchmarked against Treasuries. This is however not the case for spreads computed against the swap curve. The results based on the swap curve are very similar to the those for default swaps. This suggests that the documented underestimation of bond spreads may to a large degree be attributable to the choice of benchmark risk free curve.

Putable bonds give their owners the right to sell, or put, their bond to the issuer prior to the bond’s maturity date. Research reveals that corporate bond prices are influenced by a number of risk factors, the most important

\(^3\)We use a maximum likelihood technique developed by Duan (1994) and evaluated by Ericsson & Reneby (2002). The latter show by means of simulation experiments that the efficiency of this method is superior to the more common approach used in previous empirical studies on the use of structural models for valuing credit risky securities. See for example, Jones et al. (1984), Ronn & Verma (1986) and Hull (2000).
of which are likely interest rate risk, default risk, and illiquidity\(^4\). The option to put back the bond to the issuers appears to be designed to provide insurance against all three. While callable and convertible bonds have well-understood embedded option features, the third essay constitutes, to the best of our knowledge, the first empirical study of putable bond valuation.\(^5\)

We study a sample of more than a thousand putable bond transactions together with a control sample of prices for regular bonds issued by the same corporations. We perform a linear regression analysis on the relationship between putable and regular bond yield spreads and key default, liquidity and interest rate proxies suggested by economic theory and previous empirical research\(^6\). We find that the estimated coefficients, for both putable and regular bonds, of the three classes of proxies are not only consistent with theory, but also statistically and economically significant. Interestingly, we find that, in comparison to regular bond spreads, putable bond spreads are statistically more significant but economically less sensitive to those proxies. This suggests that put options embedded in corporate bonds help to reduce bondholders' exposures to those risks.

Intuitively, a putable bond is simply a regular bond with a put option attached. The price of a putable bond can be split into the price of a regular bond and the price of a put option. We therefore proxy the market value of the put option by the difference in yield spreads on a given day between the regular and putable bonds issued by the same corporation. We find that the put option does significantly hedge against all three risks. The reduction in corporate bond yield spread due to the presence of a put is, on average, just over 40% of the yield spread. By means of regression analysis we show that the

\(^4\)See Huang & Huang (2003) and Elton et al. (2001).  
\(^5\)An interesting related study can be found in David (2001) which develops a theoretical model of the strategic value of holding putable debt when a firm experiences a liquidity crisis.  
\(^6\)See Collin-Dufresne et al. (2001), Campbell & Taksler (2002), and Ericsson et al. (2004).
put option value (as measured by the spread reduction) is related to proxies for default, interest rate, and marketability risk.

We show that the value of a put option is positively and significantly correlated to credit proxies, including firm leverage, equity volatility, and Moody's default premium. This suggests that their value increases as default become more likely. In addition, analysis on illiquidity proxies shows that a put option is less valuable for the bonds issued by relatively large firms. A larger firm is likely to enjoy the attention of a larger number of investors and to enjoy better marketability of its securities. Furthermore, the value of a put option increases when market liquidity, as measured by the Pastor-Stambaugh Index, deteriorates. The risk-free rate shows a strong and positive correlation. This confirms the intuition that the puts are more likely to be exercised when interest rates are high, which, in turn, increases their value.

Given that we have established that put values are related to the conjectured risks, we proceed to measure that proportion of the put option value that can be attributed to insurance against those risk factors, respectively. To do this, we require a model that prices putable bonds. Accordingly, we develop a bivariate lattice model that simultaneously captures correlated default and interest rate risk. Our model is closely related to Das & Sundaram (2006). The authors develop an integrated model for pricing securities that are subject to equity risk, interest rate risk, and default risk simultaneously. Their approach is based on observed equity prices and interest rates. A constant default intensity is extracted by calibrating the model to the observed market prices of derivatives contingent on equity prices. In our model, we follow a different approach where the key sources of uncertainty are the value of a firm's assets and term structure fluctuations. We draw on recent developments in the literature on structural credit risk models and their joint model of term structure and default risk to design a practicable valuation framework.
for corporate putable bonds. This involves, in a first step, the estimation of corporate asset values, volatilities, and the historical correlation between asset values and interest rates (for which we rely on the Leland & Toft (1996) model, and maximum likelihood estimation). In a second step, we construct a recombining lattice HJM term structure model.

Our method offers a fast and accurate approach for the valuation of corporate bonds with embedded options. The model is flexible enough to be applicable to both convertible and callable bonds.

Applying the model to price regular and putable bonds, we illustrate that most of the reduction in the putable bond spread (about 60%) is due to a decrease in the default component of the spread. A third of the reduction is due to mitigated term structure risk. The smallest fraction (7%) represents a reduction in the illiquidity component of the bond spread.

Our result that the dominant source of spread reduction is due to default risk may seem somewhat surprising given that there should be significant "counterparty" risk – when default is imminent the firm may not be able to honor the insurance it has implicitly written. Consistent with this, we find that the reduction due to default risk at first increases as credit quality deteriorates, but only up to a point. As bonds approach very low rating categories, the relative spreads' reduction decreases. Thus, we do find that the put option value is significantly reduced for firms at the brink of financial distress.

The remainder of this thesis is organized as follows: Chapter 2, 3 and 4 discuss the three essays in details. Chapter 5 summarizes and concludes.
Chapter 2
Managerial Entrenchment,
Dividend Policy and Capital Structure

2.1 Introduction

Contingent claims models on the valuation of corporate securities have been used extensively to study capital structure choice. However, this literature has, by and large, ignored a central problem in corporate governance, which is the misalignment of the incentives of managers and shareholders\(^1\). The fact that shareholders rely on managers to implement financing decisions raises interesting questions: What influences self-interested managers' capital structure decisions? To what extent do their leverage choices deviate from those \textit{ex ante} optimize firm values? What are the implications for security values? It is important for the contingent claims literature to explore these questions in order to truly capture the mechanism underlying the valuation of

securities. Little work on this issue has been done so far.

This article develops a contingent claims model to investigate the impact of managerial entrenchment on corporate policies and security valuation. The model emphasizes the role that managerial agency issues play in determining both a firm's capital structure and dividend payout policies. Specifically, entrenched managers choose leverage not only to reduce the likelihood of bankruptcy but also to avoid a threat from shareholders to terminate their contract. Managers will assume the minimum amount of debt necessary and choose the minimum dividend payout rate to prevent the shareholders from exercising their threat to fire.

By comparing the optimal leverage ratios from managers' point of view to those from shareholders' point of view, I show quantitatively that self-interested managers' leverage choices deviate from those ex ante maximize firm values. With reasonable input values, the result shows that managers' leverage choices could be up to 55% lower than those optimal to shareholders. Managers choose lower leverage as they become more entrenched, consistent with empirical evidence that firms with stronger managerial control power tend to use less debt (Berger et al. (1997)). In addition, both the extent and the sensitivity of the deviations are affected by the relative bargaining strength between debtor and creditors in bankruptcy negotiations.

Little direct evidence exists on the dynamic relation between dividend payout and capital structure (Allen & Michaely (2002)). The role of managerial component in those policies remains mostly unanswered (Welch (2004)). My finding suggests that, given managerial entrenchment power, dividend yield is negatively related to leverage ratio \(^2\). This supports the notion that divi-\(^2\)Barclay et al. (1995) find that dividend yield and leverage ratio are positively correlated to firm growth opportunities (measured by market-to-book ratios), which suggests they could be positively correlated. Their finding does not contradict mine. Their study is cross-sectional and suggests a indirect relation due to a third variable. My results are for a single company for which the growth opportunities are taken as given.
Dend payout and debt financing are substitutable tools to restrict managerial self-interested activities by paying out earnings. Moreover, dividend yield is negatively affected by managerial entrenchment. When their entrenchment power reaches a certain level, managers are able to stop dividend payments altogether without provoking shareholders' firing action. My results have implications for empirical research attempting to relate dividend yield to capital structure. The evidence that leverage ratios matter more for firms with lower entrenchment suggests that empirical studies should control for entrenchment in the cross-section.

The results show that managerial agency conflicts vary with a firm's financial health. The interests of managers and shareholders become naturally aligned and shareholder-manager conflicts over risk choice and cash payout level disappear as a firm approaches bankruptcy. This evidence implies that managers' decisions on asset substitution/milking asset before default may be entirely driven by the selfish motive of increasing the value of their own rent, thus challenging the conventional explanation that managers attempt to shift wealth from debtholders to shareholders.

I gauge the impact of ex post debt renegotiation on corporate policies and security values in the presence of managerial self-interest. Entrenched managers benefit from strategic default as their human capital constitutes a part of the value to be negotiated in default. Managers' leverage choices are relatively higher in firms where ex post debt renegotiations are feasible. While the ex ante optimal leverage ratios are at the highest when debtholders possess all bargaining power in renegotiation, balanced bargaining strength between a firm and its creditors leads to maximal leverage ratios at managers' choice.

an analytical solution with perpetual debt. Leland & Toft (1996) extend the
Leland model to allow for nonperpetual debt. Anderson & Sundaresan (1996),
the implications of strategic default. Leland (1998) and Ericsson (2000) study
the effects of asset substitution and hedging policies. Francois & Morellec
(2004) and Broadie et al. (2006) examine the impact of default procedures, and
Morellec (2004) gauges the manager-shareholders conflicts through managers’
incentives for over-investment. With the exception of Morellec (2004), the
former models assume that the interests of managers and shareholders are
always perfectly aligned.

My modeling of managers’ leverage choice and payout policy is in the same
spirit as Zwiebel (1996), and Myers (2000). Zwiebel shows that self-interested
managers voluntarily take on debt as a self-commitment of restricting empire­
building to prevent takeovers. Myers (2000) valuates outside equity by ex­
amining the strategic interactions between managers and shareholders over
dividend payments in a model of an unlevered firm under certainty. This ar­
ticle generalizes their work by incorporating uncertainty, debt financing and
bankruptcy in a dynamic framework with an emphasis on quantitative exam­
ination.

The methodology of this article is inspired by Anderson & Sundaresan
(1996), who use a binomial model to study debt security design. Among con­
tingent claims models, Fan & Sundaresan (2000) point out the inadequacy of
treating dividends passively as residual cash flows. They approximate divi­
dends with total periodical payouts and investigate the implications on debt
valuation when considering shareholder optimality. This article is closest to
Morellec (2004) in terms of addressing the shareholder-manager conflicts, but
from a very different angle. Morellec studies managers’ incentives for over­
investment to explain the low debt levels observed in practice. Sharehold­
ers' control challenge plays an important role in restricting managerial over-investment. This study focuses on examining the distortion that managers consume part of the free cash flow instead of fully paying it out. It emphasizes how dividend payout is determined in the presence of managerial agency problems. To the best of my knowledge, this is the first contingent claims model to explicitly study dividend dynamics and its implications on security valuation. It allows for a direct comparison between shareholders' leverage choices and those of managers'. In addition, the model provides a framework to measure managerial entrenchment using firm leverage and dividend payout.

The remainder of the article is organized as follows: Section 2 describes the model of nonstrategic default. Comparative static analyses are carried out in section 3. Section 4 extends the model to allow for strategic default. Section 5 discusses optimal capital structure. Section 6 concludes.

2.2 The model

Consider a firm with three stakeholders: managers, shareholders and debtholders. Managers are self-interested and partially entrenched due to their contribution of firm-specific human capital to the value of the assets of the firm. The managers operate the firm and will not quit voluntarily as they derive a private rent besides salaries when being in control. $B$, $S$ and $M$ denote the values of debt, shareholders' equity and managers' rent respectively. In order to completely separate managers' interest from that of the shareholders, I assume the managers do not own any equity of the firm.$^3$

The debt is composed of coupon-bearing bonds of maturity $T$. The equity has no prespecified maturity. The firm asset value $v_t$ follows a binomial

---

$^3$This provides an upper bound for the agency cost of equity, as shareholders' and managers' interest could be better aligned by changing the remuneration scheme of the managers, such as stock option plans.
process that ends at the debt maturity⁴. Given the value \( v_t \) at each time \( t \), nature decides whether the value of the asset moves up to \( u v_t \) or down to \( d v_t \) at \( t + 1 \). This is illustrated in Figure 2.1. The risk-neutral probabilities of moving up and down are \( p \) and \( 1 - p \), respectively, where \( p \) is firm-specific and invariant to time and node. At each \( t \), the firm asset produces an observable but nonverifiable cash flow, \( \beta v_t \). The amount of the cash flow is not subject to any default, firing or liquidation decisions made at \( t \).

[insert Figure 2.1]

The shareholders can fire the managers and take over control at any time \( t \). However, this will reduce asset value by \( \phi (1 - \beta) v_t \), which represents the loss of managerial human capital. \( \phi \) reflects managerial entrenchment power. There is no information asymmetry on \( \phi \) between managers and shareholders. The managers and shareholders agree implicitly on the value of \( \phi \). If debt contract is breached, the debtholders are entitled to take over the firm. They liquidate the firm immediately after the takeover. Upon liquidation, the firm asset suffers a liquidation loss of \( \kappa (1 - \beta) v_t \) besides losing the value of managerial human capital if the managers are in control at the time. The liquidation recovery value of the firm can be expressed as \( \beta v_t + (1 - \kappa - \phi) (1 - \beta) v_t \) - this comprises the current cash flow and the residual asset value.

Strategic default and debt renegotiation are ruled out in this model. So the model applies to firms that borrow public debts from diverse bondholders, with whom aggregate consents on debt relief are extremely costly to solicit. As illustrated in Figure 2.2, on each node, the following actions are observed as in the numerical sequence:

1. The managers decide whether to pay coupon (and principal) to the debtholders (at \( T \)).

⁴Firm continues its operation after the debt maturity, if the firm has not been liquidated. The binomial process ends at the debt maturity only for the sake of valuation.
2. The debtholders accept the payment if it satisfies the debt contract. Otherwise, the debtholders take over and liquidate the firm. The game is over.

3. If there is no liquidation, the managers make a dividend offer to the shareholders.

4. The shareholders decide whether to accept the offer or not. By accepting, they pocket the money and let the managers stay in control till next time. By rejecting, they claim control and fire the managers.

Equilibrium is obtained under the assumption that all stakeholders act rationally in their own best interests. The present values of the debt, equity and managers’ rent are computed using backward induction. Thus, the valuation begins with the nodes on the debt maturity date $T$. On this date, the debtholders are entitled to receive the principal $P$ and the last coupon $cP$, where $c$ denotes coupon rate. The managers repay the debtholders the contracted amount if there is sufficient asset to fulfill the debt obligation. Otherwise, the firm defaults and is liquidated. Then the debtholders claim the liquidation recovery value. The value of the debt at $T$ is

$$
B(v_T) = \begin{cases} 
(1 + c)P, & \text{if } v_T \geq (1 + c)P \\
\beta v_T + (1 - \kappa - \phi)(1 - \beta)v_T, & \text{if } v_T < (1 + c)P.
\end{cases}
$$

(2.1)

I introduce $ER(v)$ as the sum of the values of the equity and the managers’ rent. The value of $ER(v)$ at $T$ is

$$
ER(v_T) = \begin{cases} 
v_T - B(v_T) + \tau cP, & \text{if } v_T \geq (1 + c)P \\
0, & \text{if } v_T < (1 + c)P.
\end{cases}
$$

(2.2)
where $\tau$ is the corporate tax rate. The firm could refinance its debt at the maturity of its current debt. For the sake of simplicity, I assume that the firm remains unlevered after time $T$. Therefore, the value of the firm equals its asset value $v_T$.

The operation of the firm continues if there is no default at $T$. The managers' human capital remains valuable to the firm – firing the managers will incur a loss in asset of $\phi (1 - \beta) v_T$. The managers make a dividend offer that implies an equity value of $S(v_T)$. If the shareholders reject the offer, they fire the managers and end up with a takeover equity value of $ER(v_T)$ minus the firing cost $\phi (1 - \beta) v_T$. In equilibrium, the managers match the offered equity value $S(v_T)$ with the takeover equity value $(ER(v_T) - \phi (1 - \beta) v_T)^+$ to make the shareholders indifferent about accepting or rejecting the offer. The shareholders accept it in equilibrium. The equity is worth nothing in default.

Therefore, the value of the equity at $T$ is

$$S(v_T) = \begin{cases} 
(ER(v_T) - \phi (1 - \beta) v_T)^+, & \text{if } v_T \geq (1 + c) P \\
0, & \text{if } v_T < (1 + c) P.
\end{cases}$$  \hspace{1cm} (2.3)

The managers retain the rest of the firm asset for their own rent after repaying the debtholders and offering the shareholders an equity value. The managers receive nothing on default. The value of their rent at $T$ is

$$M(v_T) = \begin{cases} 
ER(v_T) - S(v_T), & \text{if } v_T \geq (1 + c) P \\
0, & \text{if } v_T < (1 + c) P.
\end{cases}$$  \hspace{1cm} (2.4)

Interactions that take place at each time $t$ prior to the debt maturity follow the same logic. One additional complication is that the valuation takes

\footnote{Myers (2000) valuates outside equity of an unlevered firm with constant asset. In this model, the value of equity at $T$ can be estimated in the same spirit of Myers's with uncertain asset value.}

\footnote{The managers can always slightly increase the offered equity value to make the shareholders totally favor accepting the offer. $(X)^+$ means $\max (0, X)$, reflecting limited liability.}
account of the expected continuation values. I start by presenting the valuation if the firm does not default at $t$. Discussions on the default condition and the valuation in default follow. The nondefault value of the debt at $t$ equals the current coupon plus the expected continuation value of the debt, which is computed by discounting the debt values on two adjacent nodes at $t+1$ under risk-neutral probability measure:

$$B(v_t) = cP + \frac{pB(uv_t) + (1-p)B(dv_t)}{1+r} \quad (2.5)$$

where

$$u = \exp(\sigma)$$
$$d = \frac{1}{u} = \exp(-\sigma)$$
$$p = \frac{(1+r)(1-\beta) - d}{u-d}.$$

See appendix for proof. The value of $ER(v_t)$ equals the ex-coupon cash flow $\beta v_t - (1-\tau)cP$ plus the expected continuation value of $ER(v_t)$, derived under the same risk-neutral probability measure:

$$ER(v_t) = \beta v_t - (1-\tau)cP + \frac{pER(uv_t) + (1-p)ER(dv_t)}{1+r}. \quad (2.6)$$

The ex-coupon cash flow may be negative as the firm becomes financially distressed due to its incapability to generate sufficient cash flow to pay the coupon. Fire sale of asset in this situation is disallowed by debt covenants, so the managers try to raise new capital from the shareholders to service debt\footnote{Lambrecht & Myers (2005) discuss managers' incentives to delay terminating the operation of a firm. Managers lose the value of their firm-specific human capital if the firm bankrupts.}. The shareholders will contribute money to keep the firm alive only if they believe it is worthwhile. Otherwise, they refuse to inject money. Then, the firm is unable to fulfill its debt obligations and has to default. I will address the situation that provokes default in detail shortly.
To extract the maximum amount of cash flow, the managers try to pay out the minimum amount of dividend that does not trigger the termination of their contract at $t$. If the managers pay out the total ex-coupon cash flow, the shareholders do not dispute. Then the value of the equity equals the ex-coupon cash flow plus the expected continuation value of the equity. If the managers do not pay a satisfactory amount of dividend, the shareholders will fire the managers and operate the firm themselves. Then the value of the equity equals $S\left(v_t^f\right)$, where $v_t^f$ denotes the asset value after the managers have been fired. I will show how the value of $S\left(v_t^f\right)$ is computed in next subsection. It is easy to see that the value of $S\left(v_t^f\right)$ is always lower than the value of the equity associated with receiving the total ex-coupon cash flow as dividend. In equilibrium, the managers choose a dividend to signal that the value of the equity equals $S\left(v_t^f\right)$. The shareholders accept the dividend. The nondefault value of the equity at $t$ is

$$S(v_t) = \min\left(S\left(v_t^f\right), \beta v_t - (1 - \tau) cP + \frac{pS(\omega v_t) + (1 - p) S(dv_t)}{1 + r}\right) = S\left(v_t^f\right).$$  \hspace{1cm} (2.7)$$

The unpaid cash flow is retained by the managers for their own rent. The nondefault value of their rent at $t$ is

$$M(v_t) = ER(v_t) - S(v_t).$$ \hspace{1cm} (2.8)$$

When the cash flow generated at $t$ is insufficient to service debt ($\beta v_t < (1 - \tau) cP$), the shareholders decide whether to default because they contribute new capital to service debt to keep the firm alive in financial distress. Default occurs when the shareholders are no longer interested in saving the financially troubled firm – when the value of the equity falls below the equity value in liquidation. When the firm is being liquidated, the debtholders claim the contracted amount if the liquidation recovery value is higher than that. Otherwise, they claim the liquidation recovery value. The shareholders receive the residual asset if there
is any. The managers end up with nothing.

\[
B^t(v_t) = \begin{cases} 
\min (\beta v_t + (1 - \kappa - \phi) (1 - \beta) v_t, P) \\
\min (\beta v_t + (1 - \kappa - \phi) (1 - \beta) v_t, P), \text{ default}
\end{cases}
\]

\[
S^t(v_t) = \beta v_t + (1 - \kappa - \phi) (1 - \beta) v_t - B^t(v_t)
\]

\[
M^t(v_t) = 0.
\]

Combining the formulas in both nondefault and default situations, the values of the debt, equity and managers' rent at \( t \) before the debt maturity are summarized in equation (2.9), (2.10) and (2.11). The present values of the debt, equity and managers' rent are computed by repeating the valuation backward along the tree till \( t = 0 \).

\[
B(v_t) = \begin{cases} 
cP + \frac{pB(v_{t+1}) + (1-p)B(v_t)}{1+r}, \text{ nondefault} \\
\min (\beta v_t + (1 - \kappa - \phi) (1 - \beta) v_t, P), \text{ default}
\end{cases}
\]

\[
S(v_t) = \begin{cases} 
S(v_t^f), \text{ nondefault} \\
\beta v_t + (1 - \kappa - \phi) (1 - \beta) v_t - B(v_t), \text{ default}
\end{cases}
\]

\[
M(v_t) = \begin{cases} 
ER(v_t) - S(v_t), \text{ nondefault} \\
0, \text{ default.}
\end{cases}
\]

\( S(v_t^f) \) represents the value of the equity at \( t \) in case the shareholders fire the managers and operate the firm themselves later on. Suppose the shareholders take over control on a node at time \( t \), asset value drops immediately from \( v_t \) to \( v_t^f \), which equals \((1 - \phi)(1 - \beta)v_t\). This reflects the loss of managers’ human capital. The firm asset without the human capital follows a new
binomial tree that begins with \( v_t \) and ends at debt maturity. To avoid confusion, subscript \( h \) is used in this subsection to denote time along the new tree. \( u, d \) and \( p \) are firm-specific and remain the same. The firm asset generates a cash flow of \( \beta v_t \) at each time \( h \) except on the starting node because cash flow \( \beta v_t \) has already been realized before the shareholders take over control. Liquidation cost is \( \kappa v_t \) without managers’ human capital. The agency problems of equity no longer exist, so the value of the equity \( S(v_h) \) at every \( h \) is computed in the same way as valuing \( ER(v_t) \) before.

The same backward induction methodology is used to compute the values of \( S(v_h) \) at the firing time. At the debt maturity \( T \), the debtholders are repaid the contracted amount if the firm is financially able to honor the contract. Otherwise, they claim the liquidation recovery value as the firm defaults. The value of the debt at \( T \) is

\[
B(v_T) = \begin{cases} 
(1 + c) P, & \text{if } v_T \geq (1 + c) P \\
\beta v_T + (1 - \kappa) (1 - \beta) v_T, & \text{if } v_T < (1 + c) P.
\end{cases}
\]

The value of the equity equals the asset value net of the value of the debt:

\[
S(v_T) = \begin{cases} 
\begin{align*}
& v_T - B(v_T) + \tau c P, & \text{if } v_T \geq (1 + c) P \\
& 0, & \text{if } v_T < (1 + c) P.
\end{align*}
\end{cases}
\]

On each node at \( h \) prior to the debt maturity, the nondefault value of the debt equals the current coupon plus the expected continuation value of the debt. In default, the debtholders receive the contracted amount if the liquidation recovery value is higher than that. Otherwise, they recover the liquidation recovery value. The value of the debt at \( h \) is

\[
B(v_h) = \begin{cases} 
cP + \frac{pB(\omega_h) + (1-p)B(dv_h)}{1+r}, & \text{nondefault} \\
\min \left( P, \beta v_h + (1 - \kappa) (1 - \beta) v_h \right), & \text{default}.
\end{cases}
\]


The nondefault value of the equity equals the ex-coupon cash flow plus the expected continuation value of the equity. The default value of the equity is the residual asset value after the debtholders' claim.

\[
S(v^f_h) = \begin{cases} 
\beta v^f_h - (1 - \tau) cP + \frac{pS(uv^f_h) + (1 - p)S(dv^f_h)}{1+r}, & \text{nondefault} \\
\beta v^f_h + (1 - \kappa) (1 - \beta) v^f_h - B \left( v^f_h \right), & \text{default.}
\end{cases}
\] (2.15)

The default condition involves the continuing value of the equity \( S(v^f_h) \) falling below the equity value in liquidation. The value of the equity on the managers being fired \( S(v^f_h) \) is computed by repeating the valuation backward along the binomial tree till time \( t \). However, firing the managers will never happen in equilibrium because the managers can always pay a dividend to make the value of the equity equal to or slightly higher than \( S(v^f_h) \).

2.3 Comparative statics

I apply the model introduced in the previous section to investigate the impact of managerial entrenchment on firm policies and the values of the firm, debt and equity. \( \phi \), which characterizes the entrenchment power, is used as the changing parameter to carry out the analysis. I fix the total liquidation cost \( (\kappa + \phi) \) to 0.30. The purpose is to prevent the change in \( \phi \) from affecting the total liquidation cost in order to make the comparative statics more meaningful. The initial asset value \( v_0 \) is normalized to 100. The time interval between \( t \) and \( t + 1 \) is a week. The values of the other parameters are:

- Risk-free rate \( r = 7.5\% \), about the average of 10-year Treasury rates, \( 7.45\% \), during 1982-2004.
• Payout rate $\beta = 6\%$, as assumed in Huang & Huang (2003).

• Asset return volatility $\sigma = 0.25$, about the same as in Leland (2004).

• Debt maturity $T = 10$. Barclay et al. (1995) report a median debt maturity of 5 years in their sample, which implies that the average maturity of newly issued debt is 10 years.

• Effective tax rate $\tau = 0.15$, as in Leland (2004), is lower than the corporate tax rate to reflect personal tax benefits to equity returns, thus reducing the tax advantage of debt.

• Debt principal $P = 30$.

• Coupon rate $c = 8.5\%$ in the base case\(^8\).

• Total liquidation cost $\kappa + \phi = 0.30$, as in Leland (2004).

I define firm value as the sum of the values of debt and equity. Figure 2.3 (A) (B) & (C) show that managerial entrenchment reduces not only the values of debt and equity, but also overall efficiency (firm value plus managerial rent). $\phi = 0$ represents the benchmark in which the managers have no entrenchment power and act on the behalf of the shareholders. The values of the firm and equity are negatively correlated to entrenchment power – the firm value decreases monotonically from 102.30 to 87.40, and the value of equity decreases from 70.96 to 56.20 as $\phi$ increases from 0 to 0.15 in the base case. The negative relationships can be explained with two reasons: Higher entrenchment power enables managers to extract more value from the firm safely, which is reflected by the increase in the value of their rent from 0 to

---

\(^8\)According to Longstaff & Schwartz (1995), the average credit spreads on Moody's industrial bonds range from 48 bps for Aaa grade to 184 bps for Baa grade, with an average of 109 bps over the period 1977-1992. A coupon rate of the risk free rate plus 100 bps produces a yield spread of 110 bps, which roughly matches the observed average.
14.71 with $\phi$ in Figure 2.3(D). Secondly, managers' selfish actions reduce shareholders' willingness to bail the firm out of financial distress, leading to a higher likelihood of default which results in lower firm and equity values. Comparing two otherwise identical firms, the one with the higher degree of managerial entrenchment would have relatively lower firm and equity values.

As shown in Figure 2.3(B), for $\beta = 6\%$, the value of debt decreases from 31.34 to 31.19 as $\phi$ increases. It seems that $\phi$ has only a small impact on debt value. This is largely due to the fixed total liquidation cost. In reality, the impact of $\phi$ on debt value could be more significant as liquidation cost increases with $\phi$.

Figure 2.4(A) tells that increasing firm risk ($\sigma$) reduces the value of firm except when a firm is close to bankruptcy. This is consistent to the results of previous studies (see, for example, Leland (1998)). Figures 4(B), (C) and (E) show that the value of debt is always negatively correlated to firm risk, whereas the value of equity always responds positively. Interestingly, Figures 4(D) and (F) show that when a firm is not imminent to default, say when debt/asset ratio $P/V = 45\%$, the value of managers' rent decreases from 9.97 to 9.18 as asset volatility $\sigma$ increases from 0.1 to 0.5. An increase in firm risk level produces a higher likelihood of default, in which managers lose the value of their human capital. In contrast, the shareholders advocate higher risk levels because the value of equity increases from 45.83 to 56.57. The results highlight one of the conflicts between shareholders and managers over risk choice: for a financially healthy firm, shareholders would prefer to increase the risk level that produces a higher equity value. But managers would favor reducing the risk level to protect the value of their own rent. Challenging the conventional premise that managers always stay closer to shareholders than to
debtholders, it is shown that managers' preference of risk choice is the same as that of debtholders in this situation.

Figures 2.4 (D) and (F) paint a different picture of the relationship between managers' rent and risk level when a firm is close to insolvency. The value of managers' rent tends to increase with risk. For instance, when $P/V = 95\%$, the value of debt decreases from 83.12 to 57.91 as $\sigma$ increases, whereas the values of managers' rent and equity increase from 5.80 and 4.01 to 7.77 and 32.79 respectively. Managers' rent behaves like debt when a firm is financially healthy, and like equity when the firm is close to default. When a firm is close to bankruptcy, the asset substitution problem becomes economically significant, then shareholders' and managers' incentives for risk are aligned. This suggests that managerial entrenchment does not really mitigate the asset substitution problem of debt.

Conventionally, managers' decisions on asset substitution before default are explained as their attempt to transfer wealth from debtholders to shareholders. The results above suggest that asset substitution benefits not only shareholders but also managers themselves at the expense of debtholders. Managerial motives for performing asset substitution may be simply to pursue their own agenda. Overall, the preferences of shareholders and managers regarding risk choice become more aligned as a firm approaches bankruptcy.

[insert Figure 2.4]

Figure 2.5 (A) shows that the value of firm responds negatively to payout rate $\beta$ except when a firm is close to default. Figures 5 (B), (C) and (E) plot that the value of debt decreases with payout rate and that the value of equity increases with it. The value of managers' rent is negatively correlated to payout rate when a firm is distant from financial distress. For example, when $P/V = 45\%$, the value of managers' rent decreases from 9.58 to 9.28 as
β increases from 0.04 to 0.1. Managers favor lower payout rates that reduce the chance of losing their human capital in default. In contrast, the value of equity increases from 47.38 to 49.88 as payout rate increases. High cash payout policies are more attractive to shareholders than to managers. Managers’ discretionary decision favors low cash payout policies in order to protect the value of their own claims.

Figure 2.5 (D) and (F) show that the value of managers’ rent turns to increase with payout rate when a firm is on the edge of bankruptcy. For instance, when $P/V = 95\%$, the value of managers’ rent increases from 6.62 to 7.04, while the equity value increases from 13.03 to 20.76, as payout rate rises from 0.04 to 0.1. The value of debt drops from 75.72 to 69.60. Presumably, both managers and shareholders would agree to increase payout in this situation - this benefits both of them at the expense of the bondholders. The evidence suggests that managers could have selfish incentives for milking asset prior to default for the sake of their own utility. The result challenges conventional reasoning that managers attempt to shift wealth from debtholders to shareholders, because managers’ activities can be entirely driven by their own interest. Importantly, The result serves as a reminder to exercise caution when making assumptions on shareholder-manager conflicts because they change dynamically with a firm’s financial health.

There has been little direct evidence on the dynamic relation between dividend payout and capital structure and on the influence of managerial entrenchment on dividend yield. This model sheds some light on those unanswered questions. I compute dividend yield as

\[ DY(v_0) = \frac{\text{Dividend}(v_0)}{S(v_0)} \]

\[ = \frac{(\beta v_0 - (1 - \tau) cP - \Omega)^+}{S(v_0)}, \]
where $\beta v_0 - (1 - \tau)cP$ is the ex-coupon cash flow at $t = 0$. $\Omega$ represents managerial cash flow extraction at $t = 0$.

Figure 2.6 shows that dividend yields are negatively related to leverage ratios. When managers are not entrenched, dividend yield decreases from 5.93% to 1.75% as a firm increases its debt/asset ratio from 5% to 75%. The result suggests that firms with high leverages tend to have low dividend yields. Moreover, the result shows that dividend yield is negatively affected by managerial entrenchment. With $P/V = 35\%$, dividend yield decreases from 5.27% to 0.82% as entrenchment power $\phi$ increases from 0 to 0.03. As $\phi$ reaches and surpasses 0.04, managers are able to stop dividend payment without provoking shareholders’ firing action. Given the observed average dividend yield of 1.5% and the average leverage ratio of S&P500 firms of 35%, the model predicts an average managerial entrenchment power, $\phi$, of approximately 2.5%.

My results have implications for empirical research attempting to relate dividend yield to capital structure. With sufficient entrenchment, managers are able to stop dividend payments altogether without triggering shareholders’ firing actions. The evidence that leverage ratios matter more for firms with lower entrenchment suggests that empirical studies should control for entrenchment in the cross-section. In addition, as a firm becomes more mature, it has more assets in place and less investment opportunities. Hence, managerial entrenchment is presumably lower for these firms because managing assets in place is less knowledge-specific. Firm age, board membership characters and industry could be used as proxies for entrenchment.

We observe that the value of managers’ rent decreases as a firm takes on more debt, consistent with the well-documented role of debt as a discipline tool to restrict managerial value extraction. It attests that managers would
like to issue zero debt to optimize their utility. We will discuss managers' leverage choice in more detail in the optimal capital structure section.

2.4 Strategic default

Strategic default has been disallowed in previous section to separate the impact of managerial agency issues on the valuation of securities from those of agency issues of debt. In this section, I relax that restriction to examine the managerial agency conflicts in the presence of ex post debt renegotiation. A firm may choose to serve its debt strategically, knowing that debtholders will bear a liquidation loss if they force the firm to bankrupt. Some contingent claims models study strategic default and debt renegotiation without considering managerial agency issues\(^9\). Strategic default is more relevant to a firm which borrows from a few institutional creditors, with whom aggregate consents on debt relief can be obtained through renegotiation at small costs. For simplicity, I assume zero renegotiation cost in this model.

The game structure remains the same as in the base model, except that we observe the following changes: (i) payment to the debtholders may fall short of the contracted amount even if the firm is able to honor the contract; (ii) for their best interest, the debtholders may accept the below-contracted-amount payment and allow the game to continue. The game is illustrated in Figure 2.7\(^{10}\).


\(^{10}\)The realized asset value \(v_t\) has been observed before any default, coupon and dividend decisions are made. The expected equilibrium payoffs of three parties are known to all parties and taken into account to decide their interactive strategies. Therefore, The sequencing of the games does not have a significant impact on equilibrium strategies and payoffs. The sequential game that strategic default takes place before strategic dividend payout simplifies the model setup. However, it does not mean that debtholders have priority over shareholders in the non-bankruptcy states.
Backward induction begins at the debt maturity $T$. At the date, in case the firm defaults and is liquidated, the debtholders receive only the liquidation recovery value. Through renegotiation, the debtholders could receive the liquidation recovery value plus a saving from avoiding liquidation. According to the standard results of Nash Equilibrium, the saving that the debtholders receive equals a portion of $0 \leq \theta \leq 1$ of the saved liquidation loss, $(\kappa + \phi) (1 - \beta) v_T$, due to their relative bargaining power $\theta$ to the firm. In equilibrium, the managers decide whether to honor the debt contract or to default strategically, depending on in which option they repay less to the debtholders. Strategic default occurs when the value of firm asset is low. The value of the debt at maturity equals either the contracted amount or the negotiated payoff in strategic default, whichever is lower.

\[
B(v_T) = \min\left( (1 + c) P, v_T - (1 - \theta) (\kappa + \phi) (1 - \beta) v_T \right). \tag{2.16}
\]

$ER(v_T)$ represents the sum of the values of the equity and managers' rent after the debt is repaid. It equals the asset value subtracting the value of the debt:

\[
ER(v_T) = \begin{cases} 
  v_T - B(v_T) + \tau c P, & \text{nondefault} \\
  v_T - B(v_T), & \text{default}.
\end{cases} \tag{2.17}
\]

After repaying the debt, the managers offer the shareholders an equity value that renders the latter indifferent about accepting or rejecting the offer. The offered value of the equity is

\[
S(v_T) = (ER(v_T) - \phi (1 - \beta) v_T)^+ . \tag{2.18}
\]

In equilibrium, the shareholders accept the offer in equilibrium. The managers pocket the rest of $ER(v_T)$:

\[
M(v_T) = ER(v_T) - S(v_T). \tag{2.19}
\]
At each time $t$ before $T$, the managers face two options in debt service. One option is to simply honor the debt contract so that the value of the debt equals the current coupon plus the expected continuation value of the debt. The other option involves renegotiating debt payment when the asset value is low. Upon renegotiation, the debtholders receive a portion $\theta$ of the value saved through renegotiation plus the liquidation recovery value. The value saved is the difference between the firm value $V(t)$ conditional on the firm surviving to $t+1$ and the liquidation recovery value, given that a firm has higher value as an ongoing entity than when being liquidated. The value of $V(t)$ is higher than the liquidation recovery value because it contains potential future tax benefits and avoids immediate liquidation cost. In equilibrium, the managers choose the option that yields a lower debt value. The value of the debt at $t$ is:

$$B(t) = \min \left( \frac{cP + \frac{pB(uvt) + (1-p)B(dvt)}{1+r}}{\theta V(t) + (1-\theta) (1-(\kappa + \phi) (1-\beta)) v_t} \right),$$  

(2.20)

where the value of the firm as an on-going entity, $V(t)$, equals the cash flow generated at $t$ plus the expected continuation value of the firm:

$$V(t) = \beta v_t + \frac{p (B(uvt) + ER(uvt)) + (1-p) (B(dvt) + ER(dvt))}{1+r}.$$  

Strategic default is reversible – the firm defaults when its asset value is low but has to resume “normal” debt service once its asset value recovers from the default barrier. There is no tax shield on the interest payments made during strategic default. If the firm does not default at $t$, the value of $ER(t)$ equals the ex-coupon cash flow plus the expected continuation value of $ER(t)$. If the firm defaults, the value of $ER(t)$ is the ongoing value of the firm value minus the value of the debt:

$$ER(t) = \begin{cases} 
\beta v_t - (1-\tau) cP + \frac{bER(uvt) + (1-p)ER(dvt)}{1+r}, & \text{nondefault} \\
V(t) - B(t), & \text{default.} 
\end{cases}$$  

(2.21)
The managers pay out the minimum amount of dividend to the shareholders in order to maximize the value of their rent. In the case of no defaulted at \( t \), the managers either payout all ex-coupon cash flow as dividend or make a dividend payment that equates the value of the equity to the reservation value \( S(v_t^f) \). In default, the shareholders simply end up with the reservation value of equity \( S(v_t^f) \). The value of the equity is:

\[
S(v_t) = \begin{cases} 
\min \left( \beta v_t - (1 - \tau) cP + \frac{pS(u_t) + (1-p)S(d_t)}{1+r}, S(v_t^f) \right), & \text{nondefault} \\
S(v_t^f), & \text{default},
\end{cases}
\]

(2.22)

where the value of \( S(v_t^f) \) is computed in the same logic as in the nonstrategic default case. See appendix for details. The value of managers’ rent at \( t \) is:

\[
M(v_t) = ER(v_t) - S(v_t).
\]

(2.23)

### 2.5 Optimal capital structure

I apply the strategic default model to examine the optimal leverage from both shareholders’ and managers’ points of views. Debt amount is determined at financing decision time \( t = 0 \). The coupon rate, \( c \), is no longer fixed and determined at debt insurance to equate debt value to its face value \( (B = P) \). Shareholders select the \textit{ex ante} optimal leverage to maximize firm value. This is equivalent to maximizing equity value given that debt is issued at par. Managers choose leverage to optimize the value of their own utility. Then, the optimal amount of debt is determined numerically to maximize either the firm value or the value of managers’ rent. Leverage is defined as the ratio of the value of debt to firm value:

\[
L(v, P^*) = \frac{B(v, P^*)}{B(v, P^*) + S(v, P^*)}.
\]

(2.24)
I examine three scenarios with $\theta = 0$, 0.5 and 1 respectively. $\theta = 0.5$ is the benchmark as a firm and its creditors share equal bargaining power in debt renegotiations. $\theta = 1$ means that debtholders possess all bargaining power and therefore receive all liquidation avoidance savings in renegotiation. It closely resembles the nonstrategic default case in terms of discouraging the firm’s strategic default activities. This represents that creditors, in practice, exercise strong power in the determination of restructure plans in bankruptcy courts. In the scenario of $\theta = 0$, the firm detains all bargaining power against its creditors in debt renegotiation. This is quite an extreme situation in which debtholders are not well protected and strategic defaults are maximally encouraged.

Table 2.1 reports *ex ante* optimal leverages and managers’ leverage choices in the absence and in the presence of shareholders’ threat to fire at different levels of debtholders’ bargaining power.

![Insert Table 2.1]

I start by discussing the benchmark scenario when debtholders and the firm share equal bargaining power ($\theta = 0.5$). With base case parameters, the *ex ante* firm value maximizing leverage ratio is 80% when managers are not entrenched, decreasing to 74% as managerial entrenchment power, $\phi$, rises to 0.2. Managerial entrenchment could have two opposite effects on debt financing: first, it increases value extraction. Hence, shareholders would like to issue more debt to discipline managers by paying out free cash flows. On the other hand, higher entrenchment power implies greater liquidation costs that discourage debt financing as debtholders would *ex ante* demand higher premium for compensation. The second effect generally dominates the first one.

---

11I assume that debtholders’ bargaining power, $\theta$, does not change regardless of whether the firm fires the incumbent managers.
Column 12 in Table 2.1 reports managers' leverage choices in the absence of shareholders' threat to fire them. Consistent with my conjecture, managers issue zero debt to maximize the value of their rent. Although liquidation will not occur with debt renegotiation in equilibrium, managers have to share the value of their human capital with debtholders in negotiation. They would like to avoid losing any value of their human capital by issuing zero debt and eliminating completely the chance of debt renegotiation.

Given the fact that issuing debt is one of managers' standard responsibilities, some important questions arise: why do managers issue debt? why don't managers reduce existing debt to zero over time? The answer, again, lies in shareholders' threat to penalize managers. Consider if managers issue no debt at the financing decision time \( t = 0 \), firm (or equity) value will equal \((1 - \phi) V_0\). Shareholders could take over control and issue an optimal amount of debt to maximize the firm value, which is higher than \((1 - \phi) V_0\). Thus, managers have to issue some debt to avoid being fired at time \( t = 0 \). In the same vein, managers cannot reduce the existing debt below a certain amount ever after because this would invite takeover as well. For simplicity, I limit my experiment to the case that debt amount is chosen by managers at time \( t = 0 \) and cannot be changed later on.

Managers issue the minimum amount of debt to match the firm value to the one that shareholders may achieve by taking over control and applying optimal leverage. Column 6 in Table 2.1 reports managers' leverage choices that simultaneously maximize their own rent and prevent shareholders from exercising their threat to fire. The leverage ratios decrease monotonically from 68% to 50% as \( \phi \) increases from 0.05 to 0.2. Managerial self-interest causes their selections of leverage ratios to deviate from those maximized firm values. The stronger their entrenchment power is, the less debt managers are able to issue without being fired because asset value decreases by their
human capital if managers are fired at time $t = 0$. Firm values are lower at the leverage ratios chosen by the managers, compared to those at the optimal leverage ratios. The results are consistent with empirical finding that firms with stronger managerial control power tend to use less debt.

When $\theta = 0$, all liquidation avoidance savings go to shareholders and managers in negotiations. Strategic defaults are maximally encouraged and therefore occur at relatively high asset values. As a result, debtholders request higher premium *ex ante* to compensate for their higher expected loss in default, which in turn discourages the firm from borrowing debt. The optimal leverage ratios are lower and more sensitive to entrenchment, compared to their peers with stronger debtholder bargaining power. They decrease from 63% to 37% as $\phi$ increases from 0 to 0.2.

Managers do not deviate their leverage choices from the optimal ones in the presence of shareholders' control threat. As reported in Column 7, managers' leverage choices are the same as the firm value-maximizing ones. Shareholders are supposed to receive all value saved through debt renegotiation. But managers' human capital does not add any value to equity because managers retain it to themselves through dividend payments. Hence, shareholders will fire managers at the financing decision time if the latter do not lever up to the optimal level.

When $\theta = 1$, debtholders receive everything in debt renegotiation. As a result, strategic defaults are maximally discouraged and occur at relatively low asset levels. The recovery rates of debt in default are relatively high. These effects jointly make debt financing less expensive and more attractive. We observe that the firm value maximizing leverage ratios are higher than 90%. Managers' human capital constitutes a part of the renegotiation value that increases debt recovery in default and therefore reduces the cost of debt. Firm adopts high leverage ratios to take advantage of tax shield.
Managers' leverage choices deviate the most from the optimal ones in this scenario. It is shown that managers' selections of leverage ratios range from 54% to 41% as $\phi$ changes, up to 55% lower than the optimal ones. Shareholders have to be more tolerant to the deviation because if they fire the managers, the loss of human capital will reduce debt recovery in default and drive up the ex ante cost. Since managerial entrenchment is presumably lower for mature firms than growth firms because managing assets in place is less knowledge-specific, the result is consistent with the empirical evidence that mature firms have higher leverages than growth firms.

Firm values at the optimal leverages increase when debtholders possess stronger bargaining strength in debt renegotiation. Since debtholders' bargaining power in this model captures creditors' control in bankruptcy court in practice, the result echoes the finding in Broadie et al. (2006) that the first-best default outcome could be achieved if debtholders are given the control to decide when to liquidate the firm that has been taken to the Chapter 11 process by shareholders.

That, however, is not necessarily true when managerial agency issues are considered. At managers' choice, the leverage ratios and firm values are the highest when a firm and its debtholders have equal bargaining power. When the firm holds all the bargaining power ($\theta = 0$), it becomes too costly to issue a large amount of debt. At the other extreme ($\theta = 1$), shareholders' power to discipline the managers becomes limited. Thus, the leverage ratios and firm values are lower in both situations. The result suggests that balanced bargaining strength between a firm and its creditors could be the best solution in order to maximize firm efficiency in the presence of agency problems.

When it comes to restricting managerial value extraction, the results show that the value of managers' rent decreases with debtholders' bargaining power. They suggest that borrowing from the public is a more efficient approach to
discipline managers, compared to borrowing privately. It is harder for a firm to renegotiate with diverse bondholders than to work together with private creditors.

The results provide implications on firm maturity and capital structure. Managerial entrenchment is presumably lower for mature firms than growth firms because managing assets in place is less knowledge-specific. Therefore, mature firms tend to have higher leverages than growth firms. This is consistent with empirical evidence.

2.6 Conclusions

I present a dynamic valuation model on corporate securities that characterizes firm dividend policies and capital structure through the agency issues between entrenched managers and shareholders who have limited power to fire the managers. Specifically, the entrenched managers make leverage choices and undertake dividend payout decisions to optimize their own utility and to prevent the shareholders from exercising their threat to fire simultaneously.

My findings show quantitatively the degree to which managerial entrenchment negatively influences the values of the firm, debt and equity. I demonstrate that leverage choices are subject to managerial entrenchment and to the relative bargaining power of creditors. The results suggest that balanced bargaining strength between a firm and its creditors could be optimal in order to maximize firm efficiency in the presence of agency problems.

Challenging the conventional thought that managers are always closer to shareholders than to debtholders, I show that managers’ preference on risk choice/cash payout level tallies with that of debtholders when a firm is distant from financial distress. Shareholder-manager conflicts over risk choice and payout rate disappear and the interests of managers and shareholders become
naturally aligned as a firm approaches bankruptcy. The evidence serves as a reminder to exercise caution when making assumptions on shareholder-manager conflicts because they change dynamically with a firm's financial health.

Dividend yields decrease with leverage ratios and managerial entrenchment. With sufficient entrenchment, managers are able to stop dividend payments altogether without triggering shareholders' firing actions. The evidence that leverage ratios matter more for firms with lower entrenchment suggests that empirical studies should control for entrenchment in the cross-section.
2.7 Appendix

2.7.1 Computing \( u, d \) and \( p \)

The values of \( u \) and \( d \) can be easily computed following standard binomial technics. For detailed treatment, see Hull (2004) chapter 16.

In the risk-neutral world, these are

\[
V_t = \frac{puV_t + (1-p)dV_t}{1+r} + \beta V_t
\]

\[
(1+r)(1-\beta) = pu + (1-p)d
\]

\[
p = \frac{(1+r)(1-\beta) - d}{u - d}
\]

and

\[
\frac{\partial p}{\partial \beta} = -\frac{(1+r)}{u - d}.
\]

2.7.2 Computing \( S\left(v^f_T\right) \) in strategic default

I omit detailed introduction and simply provide the reader with the formula to compute \( S\left(v^f_T\right) \). The logic is exactly the same as the one in computing \( S\left(v^f_t\right) \) in the nonstrategic default case, while the equilibrium interactions are identical to valuating \( ER(v_t) \) in the with-the-managers strategic default case. At debt maturity \( T \), debt and equity values are

\[
B\left(v^f_T\right) = \min\left((1+c)P, v^f_T - (1 - \theta) \kappa (1 - \beta) v^f_T\right)
\]

\[
S\left(v^f_T\right) = \begin{cases} v^f_T - B\left(v^f_T\right) + \tau cP, & \text{nondefault} \\ v^f_T - B\left(v^f_T\right), & \text{default}. \end{cases}
\]

At \( h \) prior to maturity, debt value is

\[
B\left(v^f_h\right) = \min\left(\frac{cP + \frac{pB(uv^f_h) + (1-p)B(dv^f_h)}{1+r}}{\theta V\left(v^f_h\right) + (1 - \theta) (1 - \kappa (1 - \beta)) v^f_h}\right)
\]
where $\theta$ represents debtholders’ bargaining power. Firm value contingent on survival is

$$V(v^f_h) = \beta v^f_h + \frac{p \left( B(u^f_h) + S(u^f_h) \right) + (1 - p) \left( B(dv^f_h) + S(dv^f_h) \right)}{1 + r}.$$  

Shareholders’ equity value is

$$S(v^f_h) = \begin{cases} 
\beta v^f_h - (1 - \tau) cP + \frac{pS(u^f_h)+(1-p)S(dv^f_h)}{1+r}, & \text{nondefault} \\
V(v^f_h) - B(v^f_h), & \text{default}. 
\end{cases}$$
Table 2.1: Optimal Leverages and Security Values (Strategic Default)

This table compares the ex ante optimal leverages and managers' leverage choices in the absence and in the presence of shareholders' threat to fire at three levels of relative bargaining strength of creditors in debt renegotiation. $\phi = 0\ (1, 0.5)$ represents that creditors have no (full, equal) bargaining power in debt renegotiation.

<table>
<thead>
<tr>
<th>$\theta$ = 0</th>
<th>Ex ante Optimal Leverage</th>
<th>Managers' Leverage with Threat</th>
<th>Managers' Leverage without Threat</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\phi$ = 0.00</td>
<td>L (%) V B S M L (%) V B S M</td>
<td>L (%) V B S M L (%) V B S M</td>
<td>L (%) V B S M L (%) V B S M</td>
</tr>
<tr>
<td>63</td>
<td>105.52</td>
<td>66.55</td>
<td>38.97</td>
</tr>
<tr>
<td>58</td>
<td>99.47</td>
<td>60.56</td>
<td>38.91</td>
</tr>
<tr>
<td>51</td>
<td>93.62</td>
<td>52.87</td>
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<td>43</td>
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<td>43.49</td>
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<tr>
<td>37</td>
<td>82.33</td>
<td>38.39</td>
<td>43.93</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$\theta$ = 0.5</th>
<th>Ex ante Optimal Leverage</th>
<th>Managers' Leverage with Threat</th>
<th>Managers' Leverage without Threat</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\phi$ = 0.00</td>
<td>L (%) V B S M L (%) V B S M</td>
<td>L (%) V B S M L (%) V B S M</td>
<td>L (%) V B S M L (%) V B S M</td>
</tr>
<tr>
<td>80</td>
<td>107.10</td>
<td>85.36</td>
<td>21.74</td>
</tr>
<tr>
<td>81</td>
<td>103.01</td>
<td>85.74</td>
<td>17.27</td>
</tr>
<tr>
<td>78</td>
<td>99.44</td>
<td>83.16</td>
<td>16.28</td>
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</tr>
<tr>
<td>74</td>
<td>92.28</td>
<td>77.97</td>
<td>14.31</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$\theta$ = 1</th>
<th>Ex ante Optimal Leverage</th>
<th>Managers' Leverage with Threat</th>
<th>Managers' Leverage without Threat</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\phi$ = 0.00</td>
<td>L (%) V B S M L (%) V B S M</td>
<td>L (%) V B S M L (%) V B S M</td>
<td>L (%) V B S M L (%) V B S M</td>
</tr>
<tr>
<td>91</td>
<td>108.63</td>
<td>99.14</td>
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</tr>
<tr>
<td>91</td>
<td>105.95</td>
<td>99.02</td>
<td>6.93</td>
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<td>103.87</td>
<td>100.00</td>
<td>3.87</td>
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</tr>
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<td>92</td>
<td>100.22</td>
<td>100.00</td>
<td>0.22</td>
</tr>
</tbody>
</table>

38
Figure 2.1: Binomial Tree of Asset Value

Figure 2.2: Illustration of the game at $t$ in the model of nonstrategic default
FIGURE 2.3: THE VALUES OF THE FIRM, DEBT, EQUITY AND MANAGERS RENT AS A FUNCTION OF MANAGERIAL ENTRENCHMENT POWER $\phi$

Payout rate $\beta = 2\%$ (square line), $\beta = 4\%$ (x line), $\beta = 6\%$ (diamond line) and $\beta = 8\%$ (+ line). The x-axis represents managerial entrenchment power. It is shown that overall efficiency (the value of the firm plus managerial rent) and the values of debt and equity decrease with entrenchment, while the value of managerial rent increases with it.
Figure 2.4: The impact of $\sigma$ on the values of the firm, debt, equity and managerial rent (with $\phi = 0.1, \kappa = 0.2$)
Figure 2.4 (continue) The values of debt, equity and managers rent at selected debt/asset ratios (45% vs 95%)

(E) Diamond line - Debt at P/V = 45%; x line - Equity at P/V = 45%; * line - Debt at P/V = 95%; + line - Equity at P/V = 95%

(F) * line - Managers' rent at P/V = 45%; Star line - Managers' rent at P/V = 95%
Figure 2.5: The impact of $\beta$ on the values of the firm, debt, equity and managers' rent (with $\phi = 0.1, \kappa = 0.2$)
**Figure 2.5 (continue) The values of debt, equity and managers rent at selected debt/asset ratios (45% vs 95%)**

(E) Diamond line - Debt at P/V = 45%; x line - Equity at P/V = 45%; * line - Debt at P/V = 95%; + line - Equity at P/V=95%

(F) * line - Managers' rent at P/V = 45%; Star line - Managers' rent at P/V = 95%
Figure 2.6: Dividend yield with capital structure and managerial entrenchment power

Z axis - Dividend yield; X axis - Leverage ratio; Y axis - Entrenchment

Figure 2.7: Illustration of the game at $t$ for strategic default
Chapter 3

Can Structural Models Price Default Risk? Evidence from Bond and Credit Derivative Markets

3.1 Introduction

A widespread view amongst financial economists is that structural models of credit risk following Black & Scholes (1973) and Merton (1974), although theoretically appealing, underestimate the actual default risk discount on credit risky securities. Several studies from the 1980’s onwards document the models producing credit spreads lower than actual corporate bond spreads.\(^1\) A recent financial innovation, the credit default swap (CDS) permits the measurement of the default risk component of a corporate issuer in isolation. In addition, CDS are commonly thought to be less influenced by

\(^1\)See Jones et al. (1984), Jones et al. (1985), Ogden (1987) and Lyden & Saranati (2000).
non-default factors. The CDS market thus provides an interesting alternative source of data to reassess the empirical performance of structural models that by construction only measure default risk.

For a selection of structural models, we compare predicted levels of credit default swap (CDS) premia with their market counterparts. In contrast to what has previously found on corporate bond data, CDS premia are not systematically underestimated. In fact, one of our studied models has little difficulty on average in predicting their level.

For robustness, we also compare the models' theoretical bond spreads to their market counterparts. CDS contracts are closely related to corporate bonds by an arbitrage argument. A package of a par floating rate corporate bond and protection bought with a CDS is a risk free investment. Given that a CDS contract requires no up front payment (i.e. it is unfunded), the comparison with the bond requires taking into account the funding rate of a bondholder. In practice, this implies that the relevant measure of the bond yield spread that is comparable to the CDS price is the spread to the swap curve. In contrast most previous empirical research on corporate bonds use the Treasury curve as a benchmark. As a result we carry out our analysis using reference yield curves based both on Treasury yields and interest swap rates.

We use a simple building block approach to develop a pricing formula for credit default swaps (henceforth, CDS). The formula is applied in the framework of three distinct structural models: Leland (1994), Leland & Toft (1996) and Fan & Sundaresan (2000). By implementing multiple models, we hope to gauge the robustness of our results to specific model assumptions. An important difference between our approach and that of Longstaff et al. (2004)

\footnote{A recent study of non-default components of CDS premia can be found in Tangy & Yan (2006).}

\footnote{A more detailed explanation is provided below.}
is that we do not rely on market prices of corporate bonds or CDS as inputs to our estimation. Thus, we need not assume that CDS prices are driven solely by default risk. Instead, we estimate the structural models using firm-specific balance sheet and market data on stock prices, and then compute the term structures of risk-adjusted default probabilities and the corresponding prices for corporate bonds and CDS for the same corporate issuer.\footnote{We use a maximum likelihood technique developed by Duan (1994) and evaluated by Ericsson & Reneby (2002). The latter show by means of simulation experiments that the efficiency of this method is superior to the more common approach used in previous empirical studies on the use of structural models for valuing credit risky securities. See for example, Jones et al. (1984), Ronn & Verma (1986) and Hull (2000).} By using pairs of contemporaneous transactions and quotes for default swaps and a bond issued by the reference entity, we can compare the estimated bond yield spreads and CDS spreads with two separate sets of data.

Consistent with previous evidence, the models do systematically underpredict bond spreads when benchmarked against Treasuries. This is however not the case for spreads computed against the swap curve. The results based on the swap curve are very similar to the those for default swaps. This suggests that the documented underestimation of bond spreads may to a large degree be attributable to the choice of benchmark risk free curve.

In more detail, we find that our three models tend to systematically underestimate bond spreads and, more importantly, that this is not the case for CDS premia when Constant Maturity Treasury rates are being used as risk-free benchmark. For our base case specifications, the Leland (1994) and Fan & Sundaresan (2000) models underestimate bond spreads by 91 and 67 basis points respectively. The Leland & Toft (1996) model underestimates much less – by ca. 59 basis points. These numbers are not dissimilar to previous findings by, for example, Eom et al. (2003). When we consider CDS premia, a very different picture emerges. On comparison of model and market CDS premia we find that the Leland (1994) and Fan & Sundaresan (2000) mod-
els underestimate CDS premia by 43 and 19 basis points, much less so than for bonds, in particular for the latter. The benchmark implementation of the Leland & Toft (1996) actually underestimates CDS premia by, on average, 2 basis points. However, when swap rates are used as benchmark, the systematic underestimation by the structural models is not present. The LT model underestimates mean bond spreads by 2% only, while the underestimation by the L and FS models is significantly reduced.

In an additional effort to understand the model's performance, we relate their residuals by means of linear regressions to default risk and non-default proxies. We find little evidence of any default risk component in either bond or CDS residuals. For example, credit ratings are unable to explain residual spread levels. A variable measuring the difference between bond yield indices of different credit ratings does have explanatory power, however. This may suggest that our implementation methodology is not properly accounting for risk premia. It could also be a result of non-default components present in those indices. In the residuals for bonds, we find evidence of an illiquidity component of between 10 and 20 basis points. CDS residuals reveal no such component.

Taken together with our results on levels of bond spreads and CDS premia, this is consistent with reasonably specified structural models being able to capture the default risk priced in bond and credit derivative markets. Past results on the underestimation of bond spreads may be an effect of ignoring the funding cost of bond investors.

The remainder of this paper is structured as follows. The following Section introduces the models and Section 3 the empirical methodology. Thenceforth, section 4 describes both the bond and CDS datasets. Section 5 draws out the implications of the results and finally, section 6 concludes.
3.2 Setup

Here we initially present the three structural models that we will study. The ensuing description is brief and we refer the reader to the original papers for details. These do not, however, treat the valuation of credit default swaps. Therefore, we utilize a simple building block approach to demonstrate how to value a CDS and its reference bond.

3.2.1 The models

Consider first the common characteristics of the three structural models: Leland (1994), Leland & Toft (1996) and Fan & Sundaresan (2000). The fundamental variable in all models is the value of the firm's assets (the unlevered firm), which is assumed to evolve as a geometric Brownian motion under the risk-adjusted measure:

\[ d\omega_t = (r - \beta)\omega_t dt + \sigma\omega_t dW_t \]

The constant risk-free interest rate is denoted \( r \), \( \beta \) is the payout ratio, \( \sigma \) is the volatility of the asset value and \( W_t \) is a standard Wiener-process under the risk-adjusted measure.

Default is triggered by the shareholders' endogenous decision to stop servicing debt. The exact asset value at which this occurs is determined by several parameters as well as the characteristics of the respective models, but is always a constant which we denote by \( L \).

The value of the firm differs from the value of the assets by the values of the tax shield and the expected bankruptcy costs. Coupon payments are tax deductible at a rate \( \tau \) and the realized costs of financial distress amount to a fraction \( \alpha \) of the value of the assets in default (i.e. \( L \)). In this setting, the value of the firm (\( F \)) is equal to the value of assets plus the tax shield (\( TS \))
less the costs of financial distress ($BK$). The value of the firm is, of course, split between equity ($E$) and debtholders ($D$) and thus all models share the following basic equalities:

\[
F(\omega_t) = \omega_t + TS(\omega_t) - BK(\omega_t)
\]

\[
= E(\omega_t) + D(\omega_t)
\]

Note that the formulae for the components depend on the model, but that they are all independent of time.

In the interest of brevity, the formulae are relegated to the appendix, and this paper merely discusses differences between the applied models. First, Leland (1994) is a natural benchmark model where debt is perpetual and promises a continuous coupon stream $C$. Financial distress triggers immediate liquidation and no renegotiation is possible.

In Leland & Toft (1996), the firm continuously issues debt of maturity $\gamma$; therefore, the firm also continuously redeems debt issued many years ago. Hence, at any given time, the firm has many overlapping debt contracts outstanding, each serviced by a continuous coupon. Coupons to individual debt contracts are designed such that the total cash flow to debt holders (the sum of coupons to all debt contracts plus nominal repayment) is constant. Letting $\gamma \to \infty$, the model converges to the Leland model. For shorter maturities, the need to redeem debt places a higher burden on the firm's cash flows. Consequently, the default barrier in the Leland & Toft model tends to be much higher than in the Leland model for short and intermediate debt maturities.

In Fan & Sundaresan (2000) debt is, as in Leland, single-layered and perpetual but creditors and shareholders can renegotiate in distress to avoid inefficient liquidations. Consequently, the default barrier in the former model is typically lower than in its Leland counterpart. To the extent that equity hold-
ers can service debt strategically, bondholder bargaining power is captured by the parameter $\eta$. If the bargaining power is nil, no strategic debt service takes place and the model converges to the Leland model.

3.2.2 Valuing the bond

Next think about what kind of real world ‘debt’ the authors had in mind when building the three structural models above. A firm’s debt consists of bank loans, bonds, accounts payable, salaries due, accrued taxes etc. Dues to suppliers, employees and the government are substitutes for other forms of debt. Part of the price of a supplied good and part of salary paid can be viewed as corresponding to compensation for the debt that, in substance, it constitutes. The cost of debt consequently includes not only regular interest payments to lenders and coupons to bondholders, but also fractions of most other payments made by a company. Clearly, a comprehensive model of all these payments would not be tractable and we think of the three models as portraying firms’ aggregate debt rather than a particular bond issue – such as the reference obligation of the CDS.

However, we do need a pricing formula which also accounts for the reference obligation – for robustness, we will let the models price both the CDS and the corresponding bond in order to investigate whether the overestimation of the spread is indeed smaller in the former case. To this end, we apply a bond pricing model that takes discrete coupons, nominal repayment and default recovery into account.\(^5\) To express the value of the bond we make use of two building blocks, a binary option $H(\omega_t, t; S)$ and a dollar-in-default claim $G(\omega_t, t; S)$. The former pays off $1$ at maturity $S$ if the firm has not defaulted before that, the latter pays off $1$ upon default should this occur before $S$;

\(^5\)This bond pricing model was used in Ericsson & Reneby (2004) and was shown to compare well to reduced form bond pricing models.
value of both depend upon the firm's asset value $\omega_t$ and current time $t$. The formulae for the binary option and the dollar-in-default claim are, for a given default barrier $L$, identical in all three structural models.

**Proposition 1** A straight coupon bond. The value of a coupon bond with $M$ coupons $c$ paid out at times $\{t_i : i = 1..M\}$ is

$$ B(\omega_t, t) = \sum_{i=1}^{M-1} c \cdot H(\omega_t, t; t_i) + (c + P) \cdot H(\omega_t, t; T) + \psi P \cdot G(\omega_t, t; T) $$

The formulae for $H$ and $G$ are given in the appendix.

The value of the bond is equal to the value of the coupons ($c$), the value of the nominal repayment ($P$) plus the value of the recovery in a default ($\psi P$). Each payment is weighted with a claim capturing the value of receiving $1$ at the respective date.

Note that the above formula for the reference bond is not directly related to the debt structure of the firm. Specifically, coupon payments to the bond are unaffected by the strategic debt service in the Fan & Sundaresan model, and by the debt redemption schedule elaborated in the Leland & Toft model. The choice of model affects the bond formula solely via the default barrier $L$.

### 3.2.3 Valuing the CDS

A CDS provides insurance for a specified corporate bond termed the reference obligation. The firm issuing this bond is designated the reference entity. The seller of insurance, the protection seller, promises, should a default event...
occur, to buy the reference obligation from the protection buyer at par.\textsuperscript{6} The credit events triggering the CDS are specified in the contract and typically range from failure to pay interest to formal bankruptcy. For the CDS, the protection buyer pays a periodic fee rather than an up-front price to the seller. When and if a credit event occurs (at time $T$), the buyer is also required to pay the fee accrued since the previous payment. Hence fee payments, although due at discrete intervals, fit nicely into a continuous modelling framework. Note also that there is no requirement that the protection buyer actually own the reference obligation, in which case the CDS is used for speculation rather than protection.

The valuation of a CDS thus involves two parts, the premium paid by the protection buyer and the potential buy-back by the protection seller. Letting $T^*$ denote maturity of the CDS and $Q$ the fee, the value of the premium at time $t$ is

$$E'[\int_t^{T^*} e^{-r(s-t)} \cdot Q \cdot I_{T<\tau_s} ds]$$

where we let $I_{T<\tau_s}$ be the indicator function for nondefault before $s$ and $E'$ denotes the expectations under the standard pricing measure. The maturity of the credit default swap is typically shorter than the maturity of the reference obligation ($T$). In fact, the by far most common maturity in practice is $T^* = 5$ years.

Assume that a bond holder in the event of bankruptcy recovers a fraction $\psi$ of par, $P$. The second part of the value of a CDS therefore is the expected value of receiving, upon default of the firm, the difference between the bond’s face value and its market price, $P - \psi P$:

$$E'[e^{-r(T-t)} \cdot (P - \psi P) \cdot I_{T<\tau}]$$

The expectation is conditional on default occurring before maturity of the

\textsuperscript{6}In practice, there may be cash settlement or delivery of another (non-defaulted) bond in place of direct purchase but we refrain from that complication here.
CDS. Using the previously outlined building blocks, we can formalize the value of a CDS in the following proposition.

**Proposition 2** Assume a CDS involves receiving an amount \( P - \psi P \) if \( T < T^* \), and paying a continuous premium \( q \) until \( \min(T^*, T) \). The value of the CDS is

\[
CDS(\omega_t, t) = (P - \psi P) \cdot G(\omega_t, t; T^*) - \frac{Q}{r} \left( 1 - H(\omega_t, t; T^*) - G(\omega_t, t; T^*) \right)
\]

The first leg of the CDS-formula captures the value of receiving the bond’s face value in case of default. The second leg captures the cost of paying the premium as a risk-free, infinite stream \( \left( \frac{Q}{r} \right) \) less two terms: the first \( (H) \) reflecting the discount attributable to the finite maturity of the swap, and the second \( (G) \) reproducing the discount due to disrupted payments when and if default occurs.

Typically, the fee is chosen so that the credit default swap upon initiation \((t = 0)\) has zero value:

\[
Q = \frac{r \cdot (P - \psi P) \cdot G(\omega_0, 0; T^*)}{(1 - H(\omega_0, 0; T^*) - G(\omega_0, 0; T^*))}
\]

(3.2)

Often the fee is expressed as a fraction of the reference obligation’s face value, and we will refer to the ratio \( q = \frac{Q}{P} \) as the credit default swap premium.

Intuitively, holding a CDS together with the reference obligation is close to holding the corresponding risk-free bond only. The positions are not identical, however, since the CDS typically has a different maturity and assures its holder the nominal amount \( (P) \), rather than value of the risk free bond \( (B) \), upon default. Yet, it is often convenient to think of the default swap premium of a just initiated swap as akin to the spread on the underlying corporate bond.
3.3 Empirical method

In the previous section we laid down the pricing formulae for stocks, credits default swaps and bonds. In this section we discuss issues related to the practical implementation of our framework. Table 3.1 lists the notation used and the assigned parameter values; these are discussed below.

[insert Table 3.1]

The following inputs are needed to price bonds and CDS using Propositions 1 and 2:

- the bond's principal amount, $P$, the coupons $c$, maturity $T$ and the coupon dates
- the recovery rate of the bond, $\psi$
- the risk-free interest rate, $r$
- the total nominal amount of debt, $N$, coupon $C$ and maturity $Y$ (Leland & Toft only)
- the bargaining power of debtholders $\eta$ (Fan & Sundaresan only)
- the costs of financial distress, $\alpha$
- the tax rate, $\tau$
- the rate, $\beta$, at which earnings are generated by the assets, and finally
- the current value, $\omega$, and volatility of assets, $\sigma$

Details of the bond contract are readily observable. However, the recovery rate of the bond in financial distress is not. We set it equal to 40%, roughly consistent with average defaulted debt recovery rate estimates for US entities.
between 1985-2001. For the risk-free rate we use constant maturity Treasury yields interpolated to match the maturity of the corporate bond or the CDS.

The nominal amount of debt equals the total liabilities taken from the firms’ balance sheets. For simplicity, we assume that the average coupon paid out to all the firm’s debt holders equates the risk-free rate: $C = r \cdot N$. To apply the LT model, we also need to specify the maturity of newly issued debt, $T$. This choice turns out to be important and at the same time difficult to pin down; therefore, we will display results for three choices of maturity: 5, 6.76, and 10 years. In Fan & Sundaresan, maturity is, by design, infinite but in contrast, we need the bargaining power of debtholders – we use 0.5. Finally, we assume that 15% of the firm’s assets are lost in financial distress before being paid out to debtholders and fix the tax rate at 20%.8

The cash flow parameter $\beta$ is of crucial importance. We, therefore, opt for a dual approach. The first assigns its value exogenously (using 0% and 6%), and the other predicts it as a weighted average of the historical dividend yield and relative interest expense. The average of weighted cash flow parameter $\beta$ is 2.65% in our sample.

We then require estimates of asset value and volatility. The methodology utilized, first proposed by Duan (1994) in the context of deposit insurance, uses price data from one or several derivatives written on the assets to infer the characteristics of the underlying, unobserved, process. In principle, the “derivative” can be any of the firm’s securities but in practice, only equity is likely to offer a precise and undisrupted price series.

---

7 We consider the average debt maturity (3.38 years) reported by Stohs & Mauer (1996) which represents a reasonable average maturity of new debt ($6.76 = 3.38 \times 2$ years).

8 The choice of 15% distress costs lies within the range estimated by Andrade & Kaplan (1998). The choice of 20% for the effective tax rate is consistent with the previous literature (see e.g. Leland (1998)) and is intentionally lower than the corporate tax rate to reflect personal tax benefits to equity returns, thus reducing the tax advantage of debt.
The maximum likelihood estimation relies on a time series of stock prices, 
\( E_{\text{obs}}^{\text{obs}} = \{ E_i^{\text{obs}} : i = 1...n \} \). A general formulation of the likelihood function using a change of variables is documented in Duan (1994). If we let \( w \left( E_i^{\text{obs}}, t_i; \sigma \right) = E^{-1} \left( E_i^{\text{obs}}, t_i; \sigma \right) \) be the inverse of the equity function, the likelihood function for equity can be expressed as

\[
L_{\omega} \left( E^{\text{obs}}; \sigma \right) = L_{\ln \omega} \left( \ln w \left( E_i^{\text{obs}}, t_i; \sigma \right) : i = 2...n; \sigma \right) = \sum_{i=2}^{n} \ln \omega_i \left. \frac{\partial E \left( \omega_i, t_i; \sigma \right)}{\partial \omega_i} \right|_{\omega_i = w \left( E_i^{\text{obs}}, t_i; \sigma \right)}
\]

\( L_{\ln \omega} \) is the standard likelihood function for a normally distributed variable, the log of the asset value, and \( \frac{\partial E}{\partial \omega_i} \) is the "delta" of the equity formula.

An estimate of the asset values is computed using the inverse equity function: \( \hat{\omega}_t = w \left( E_n^{\text{obs}}, t_n; \sigma \right) \). Once we have obtained the pair \( (\hat{\omega}_t, \sigma) \) it is straightforward to compute the estimated CDS fee using (3.2). The bond spread is calculated by solving the bond price formula in Proposition 1, computing the risky yield, and subtracting the yield for the corresponding risk free bond.\(^9\)

### 3.4 Data

To perform our estimation, we require price data on credit default swaps and corporate bonds as well as balance sheet and term structure information.

CreditTrade (CT) market prices are credit default swap (CDS) bids and offers that have either been placed directly into their electronic trading platform by traders, or entered into their database by their voice brokers who receive orders by telephone. Our database includes quotes and trades from June 1997 to April 2003. However, the early years' volumes are minimal and only as of 1999 does the volume become significant. The database distinguishes between bid

\(^9\) This bond is valued as a hypothetical bond with the same promised payments as the risky bonds but with yield equal to a linear interpolation of bracketing constant maturity Treasury (CMT) yield indices.
and offers, and between quotes and trades. The evolution of credit ratings of
the underlying debt by Moody's and S&P is recorded from COMPUSTAT. In
the early part of our sample, restructuring is considered a credit event. From
the very end of 2002 onwards, restructuring is no longer considered a credit
event of the CDSs. The underlying debt is almost exclusively senior. All con-
tracts are USD denominated. For consistency, we retain only CDS on senior
unsecured debt with restructuring as default event. Very little information is
lost with the use of each of these filters.

Our bond transaction data is sourced from the National Association of
Insurance Commissioners (NAIC). Bond issue - and issuer - related descriptive
data are obtained from the Fixed Investment Securities Database (FISD). The
majority of transactions in the NAIC database take place between 1994 and
2003.

Cleaning-up of the raw NAIC database was carried out in three steps.
In the first, bond transactions with counterparty names other than insur-
ance companies and Health Maintenance Organizations (HMOs) are removed.
Transactions without a clearly defined counterparty are deemed unreliable.

In the second step, we restricted our sample to fixed coupon rate USD
denominated bonds with issuers in the industrial sector. Furthermore, we
eliminated bond issues with option features, such as callables, putables, and
convertibles. Asset-backed issues, bonds with sinking funds or credit enhance-
ments were also removed to ensure bond prices in the sample truly reflect the
underlying credit quality of issuers.

The third step involves selecting those bonds for which we have their is-
suers' complete and reliable market capitalizations as well as accounting in-
formation about liabilities. Daily equity values are obtained from DATAS-
TREAM. Quarterly firm balance sheet data is taken from COMPUSTAT.

In total, 145 firms qualify in both the CT and NAIC databases. When we
take an intersection of the CT and NAIC data, while requiring a transaction and / or quote for the bonds and default swaps on the same name during the same day, we are left with 1387 pairs from 116 distinct entities.\textsuperscript{10}

Table 3.2 identifies descriptive statistics for firm, bond and CDS features. In Table 3.2 we see that firm sizes vary from 2.0 billion to 78.4 billion with an average of 67.9 billion dollars. Bond issuers' / CDS reference entities' S&P credit ratings range between AA and CCC while the majority lies between BBB+ and BBB. The average bond issue size is 593 million dollars, with 0.65 million and 5,000 million as extremes. The average transaction size is approximately 5.9 million dollars. On average, bonds were 3.9 years of age and had 9.7 years remaining to maturity. The average coupon rate is 6.9 percent across all issues. The longest maturity of CDS in our sample is 10 years versus 0.3 years as the shortest. The average maturity is 4.9 years.

[insert Table 3.2]

Table 3.3 presents the distribution of market CDS and bond spreads over different ratings. As expected, the CDS premia, like bond yield spreads, are largely determined by the reference entity's / issuer's credit quality. Moreover, when Treasury rates are used as riskfree benchmark, bond spreads lead over CDS premia across all rating categories save one (BB-, where there are only five observations). CDS premia only represent 33% of bond spreads for the AA range, but this fraction increases steadily to ca. 81% for a BB rating. For lower ratings, for which we have less data, the pattern is no longer as clear, but the ratio remains much higher than for high grade issuers. This is suggestive of a proportionally larger non-default component in bond yield spreads over Treasury rates for issuers with little default risk. This pattern largely disappears when swap rates are used.

\textsuperscript{10}Note that since we are not using the bond prices and CDS premia in our estimation, we do not require any matching or bracketing between bond and CDS maturities.
3.5 Results

We first briefly characterize the outcome of implementing each model in terms of among other measures the asset value and volatility estimates, before turning to the main results – the corresponding predicted CDS premia and bond spreads. Table 3.4 reports these estimates when the Treasury curve is used as benchmark (Panel A) and when the swap curve is used (Panel B). Both panels show that the Leland (1994) (L) and Fan & Sundaresan (2000) (FS) models yield approximately the same asset value and volatility estimates on average, whereas the Leland & Toft (1996) (LT) model produces higher asset value but lower asset volatility. The reason is that the higher barrier in the latter model, ceteris paribus, increases the theoretical equity volatility and lowers equity value. Hence the model will predict a higher asset value and/or a lower volatility to match observed equity volatilities. As a measure of the combined effect of asset value and volatility we also report a KMV-style distance-to-default, i.e. $\frac{L}{\sigma}$. This shows that the higher asset value and lower volatility estimates in the LT model are sufficient to compensate the effect of the higher barrier; the model produces the same distance-to-default as the Leland model does (2.8), which the FS model has the highest (2.7). The LT model reports the highest the average values of dollar-in-defaults of 2 and 10 years maturity. Therefore, the LT model is expected to produce the highest CDS / bond spreads, followed by FS and finally L.

It is interesting to note that the choice of benchmark curve has a negligible effect on the estimation of asset value and volatility. Nevertheless, as we will
see shortly, the choice is critical to the measurement of bond yield spreads and thus to assess model performance.

Table 3.5 reports the estimated asset value volatilities of various credit rating by the LT model. Our results of 23% on average closely resemble that of 22% in Schaefer & Strebulaev (2004). Although there are some differences across rating categories, for those where the bulk of our data lies (A and BBB ratings) we are well aligned.

[insert Table 3.5]

In addition Figure 3.1 plots the time series of average asset values, volatilities, leverage and market capitalization across the firms in the sample. At least two patterns become apparent. First, volatility was higher between 1999 and 2001. This is visible not only in Panel A that plots asset volatility but also in Panels B and C which summarize asset and equity values. At the same time, leverage increases during the beginning of our sample and appears to stabilize at around 50% as of the second half of 2001.

[insert Figure 3.1]

Notice that the time series of these means appear highly volatile. This can at least partly be attributed to the time varying composition of our transaction data: two consecutive means are unlikely to derive from the same (small) subset of firms.

Now we turn our attention to CDS premia estimated by the three models, reported in tables 6-8, together with results for bond spreads. Using Treasury rates as riskfree benchmark, the L, FS and LT models produce mean CDS premia of 69, 93 and 110 bps respectively compared to the observed mean CDS premium of 112 bps. Thus, our perhaps most plausible model specification produces CDS premia close to market quotes. The results show that the
estimated CDS premia are not significantly affected by the choice of riskfree rates. The L, FS and LT models produce mean CDS premia of 62, 88 and 107 bps respectively, using swap rates as riskfree input. In addition, it is interesting to note that the mean market CDS premium 112 bps is almost identical to the mean market bond spreads 111 bps when swap rates are used as riskfree rates.

As expected, when Treasury rates are used as riskfree benchmark, the L model estimates the lowest mean bond spread, 82 bps, while the FS and LT models estimate mean bond spreads of 107 bps and 114 bps, respectively. Compared to the mean market bond spread of 173 bps, they substantially underestimate bond yield spreads by 53%, 38% and 34%. This is in line with the findings of previous studies\(^\text{11}\). However, when swap rates are used as riskfree benchmark, the L, FS and LT models estimate mean bond spreads of 73, 99 and 109 bps respectively, in comparison to the mean market bond spread of 111 bps. They underestimate bond yield spreads by 34%, 11% and 2%. The LT model produces fairly accurate spread predictions on average in this case.

\[
\text{[insert Table 3.6, 3.7 & 3.8]}
\]

The pricing of CDS contracts is tied to that of corporate bonds by an arbitrage argument. A package of a corporate par floating rate note and default protection through a CDS is theoretically a risk free investment. Given that a CDS contract is unfunded, i.e. requires no up front payment, comparing bond yield spreads to CDS spreads requires taking into account the funding rate of a bondholder, which is likely in the vicinity of swap rates. Thus, in practice, this implies that the bond spread most comparable to the CDS price is the spread to the swap curve. Given that structural models do not explicitly account for

\(^{11}\text{See for example Jones et al. (1984), Ogden (1987) and Lyden & Saranati (2000). The numbers are also comparable to what Huang & Huang (2003) find for various models in an extensive calibration exercise.}\)
funding above the commonly used proxies for the risk free rate, it would seem reasonable to expect them to perform better on CDS than on bonds, where funding does not need to be adjusted for. Using the swap curve can then be viewed as a pragmatic approach to correcting for the cost of funding when implementing a structural model for bonds.

To assess the sensitivity of our results we also report estimated premia for alternative values of the cash flow rate and, for the LT model, bond maturity. The cash flow rate tends to increase bond spreads and CDS premia because firms with higher cash payout rates grow less and thus have higher default probabilities. For instance, when Treasury are used as riskfree rates, increasing $\beta$ can help to reduce the yield spreads and CDS premia underestimation for the Leland and FS models, although not eliminate it. For the LT model, bond yield spread underestimation persists. For CDS premia, the parameter can tilt the balance although at 6%, CDS premia are clearly overstated. The weighted average method of estimating $\beta$, provides reasonable results for CDS premia in the LT model.

Note that both 0% and 6% are extreme values. Few if any firms will issue debt and finance coupons entirely out of newly raised equity. A payout rate of 6% is more than two times higher than the typical weighted average between firms' dividend yields and interest expenses. Thus numbers reported at these values should illustrate the highest and lowest spreads / premia that can be obtained by varying this parameter.

For debt maturity in the LT model we consider three values:5, 6.76 and 10 years. Note that the maturity parameter in this model represents the maturity of newly issued debt. It should, therefore, exceed the average maturity of a firm's debt. On the other hand, a firm's debt consists not only of bonds but also of a variety of credits with very short maturity. Consequently, although many firms issue bonds with maturities exceeding 10 years, they are likely to also
issue medium-term notes, short-term commercial paper, while also indirectly borrowing from their suppliers, the government and their employees. It seems unlikely that the average maturity of new debt exceeds ten years.

Figure 3.2 plots the time series of average model and market bond and CDS spreads for the two benchmark curves using the benchmark LT specification. It seems that on average the models do a reasonable job of matching market spreads for CDS and for bonds when the swap curve is used as benchmark. The exception is during 2000, when the model overshoots. Interestingly this precedes a period with a historically very high incidence of defaults.

[insert Figure 3.2]

Next, we consider the residuals, defined as the difference between market and model bond or CDS spreads. Figure 3.3 plots the time series of the difference between the average bond and CDS residuals for the two choices of benchmark yield curve. The difference between the residuals \( R \) for the Treasury curve would equal

\[
R_{\text{bond}} - R_{\text{CDS}} = y_{\text{Mkt}} - y_T - (y_{\text{Mod}} - y_T) - (CDS_{\text{Mkt}} - CDS_{\text{Mod}})
\]

where \( y_{\text{Mkt}} \) and \( y_{\text{Mod}} \) denote the market and model bond yields respectively, \( y_T \) the corresponding Treasury yield and \( CDS_{\text{Mkt/Mod}} \) the default swap spreads. The model predicted bond and CDS spreads are approximately the same for a given maturity\(^{12}\). Hence

\[
R_{\text{bond}} - R_{\text{CDS}} = y_{\text{Mkt}} - y_T - CDS_{\text{Mkt}}.
\]

This can be rewritten

\[
R_{\text{bond}} - R_{\text{CDS}} = (y_{\text{Mkt}} - y_S) - CDS_{\text{Mkt}} + (y_S - y_T),
\]

where \( y_S \) denotes the swap yield. The last component, \( (y_S - y_T) \), corresponds to the swap spread and whereas the (negative of the) first is known as the CDS basis by practitioners. This is a measure of relative pricing in the cash and derivative markets for default risk. It would be interesting in itself to study this variable but this lies outside the scope of this paper. What is important for our purposes is the swap spread component.

\(^{12}\)The coupon rate also influences this relationship as the arbitrage is only exact for a par floater.
It suggests that the difference in residuals relative to the Treasury curve will largely be driven by this spread\textsuperscript{13}. The top panel in Figure 3.3 confirms this by showing that when the swap spread is high, the difference in the residuals is high and vice versa. The bottom panel plots the difference in residuals when the swap curve is the chosen benchmark. In that case, the above argument suggests that the main driver should be the basis.

[insert Figure 3.3]

To better understand the drivers of the residuals, we perform a linear regression analysis of their cross section and time series. The results of which are reported in Tables 3.9 & 3.10. Table 3.9 summarizes the impact of common variables on the time series of average residuals for bonds and CDS using both benchmark curves. The explanatory variables are the 5 year CMT rate, the default premium as measured by the difference between Moody's Baa and Aaa spread indices, the 5 year swap rate, the S&P 500 return and the VIX. Only one variable is systematically statistically significant - the S&P 500 return. This result may seem surprising given that individual firms' equity prices are inputs to the estimation of bond and CDS premia. One interpretation is that the information in equity prices for contemporaneous bond and CDS spreads may not be sufficiently accurate about the default risk premium component of the spread and that this is captured by the market return variable. For bonds residuals, the default premium is significant but this is not the case for CDS residuals. This could be a sign of the presence of a bond market specific risk which does not spill over to the CDS market.

[insert Table 3.9 & 3.10]

To attempt to explain the cross section of residuals, we average across time for each firm. Then firm specific averages are regressed on bond and firm

\textsuperscript{13}We thank Stephen Schaefer for this insight.
specific variables: the bond coupon rate, the bond transaction size, the size of the bond issue, firm size, bond maturity and a dummy that measures bond age (OTR). None of these variables are significant for residuals of either bonds or CDS. The explanatory power is consistently low for these regressions.

### 3.6 Concluding remarks

Using a set of structural models, we have evaluated the price of default protection for a sample of US corporations. We find that one of our studied models has little difficulty in predicting default swap premia on average. This result departs from what has been found in corporate bond markets. For robustness, we perform the same exercise for bond spreads by the same issuers on the same trading date. As previous work has found, bond spreads relative to the Treasury curve are systematically underestimated. However, this is not the case when the swap curve is used as a benchmark, suggesting that previously documented underestimation results may be sensitive to the choice of risk free rate. A reason why the swap curve may be a more appropriate benchmark for corporate bond spread measurement is that it lies closer to the cost of funding for traders in the bond market. The bond spread over the swap curve thus measures the additional yield these market participants require to participate in this market when faced with the alternative of dealing in credit derivatives.
3.7 Appendix

3.7.1 Building blocks for CDS and bonds

First, define default as the time \( T \) the asset value hits the default boundary from above, \( \ln \frac{\omega_t}{L_t} \equiv 0 \). Then define \( G(\omega_t, t) \) as the value of a claim paying off $1 in default:

\[
G(\omega_t, t) \equiv E^B [e^{-r(T-t)} \cdot 1]
\]

We let \( E^B \) denote expectations under the standard pricing measure. The value of \( G \) is given by

\[
G(\omega_t, t) = \left( \frac{\omega_t}{L_t} \right)^{-\theta}
\]

with the constant given by

\[
\theta = \frac{\sqrt{(h^B)^2 + 2r + h^B}}{\sigma}
\]

and

\[
h^B = \frac{r - \beta - 0.5\sigma^2}{\sigma}
\]

Define the dollar-in-default with maturity \( G(\omega_t, t; T) \) as the value of a claim paying off $1 in default if it occurs before \( T \)

\[
G(\omega_t, t; T) \equiv E^B [e^{-r(T-t)} \cdot 1 \cdot (1 - I_{T < T})]
\]

and define the binary option \( H(\omega_t, t; T) \) as the value of a claim paying off $1 at \( T \) if default has not occurred before that date

\[
H(\omega_t, t; T) \equiv E^B [e^{-r(T-t)} \cdot 1 \cdot I_{T < T}]
\]

\( I_{T < T} \) is the indicator function for the survival event, i.e. the event that the asset value \( (\omega_T) \) has not hit the barrier prior to maturity \( (T \not\leq T) \). The price formulae for the last two building blocks are given below. They contain a term that expresses the probabilities (under different measures) of the survival event.
or, the *survival probability*. To clarify this common structure, we first state those probabilities in the following lemma.\textsuperscript{14}

**Lemma 3** The probabilities of the event \( T \not\leq T \) (the "survival event") at \( t \) under the probability measures \( Q^m : m = \{ B, G \} \) are

\[
Q^m (T \not\leq T) = \phi \left( k^m \left( \frac{\omega_t}{L_t} \right) \right) - \left( \frac{\omega_t}{L_t} \right)^{-\frac{3}{2} k^m} \phi \left( k^m \left( \frac{L_t}{\omega_t} \right) \right)
\]

where

\[
k^m (x) = \frac{\ln x - h^m \sqrt{T - t}}{\sigma \sqrt{T - t}} + h^m \sqrt{T - t}
\]

\[
h^G = h^B - \theta \cdot \sigma = -\sqrt{(h^B)^2 + 2r}
\]

\( \phi (k) \) denotes the cumulative standard normal distribution function with integration limit \( k \).

The probability measure \( Q^G \) is the measure having \( G (\omega_t, t) \) as numeraire (the Girsanov kernel for going to this measure from the standard pricing measure is \( \theta \cdot \sigma \)). Using this lemma we obtain the pricing formulae for the building blocks in a convenient form. The price of a down-and-out binary option is

\[
H (\omega_t, t; T) = e^{-r(T-t)} \cdot Q^B (T \not\leq T)
\]

The price of a dollar-in-default claim with maturity \( T \) is

\[
G (\omega_t, t; T) = G (\omega_t, t) \cdot (1 - Q^G (T \not\leq T))
\]

To understand this second formula, note that the value of receiving a dollar if default occurs prior to \( T \) must be equal to receiving a dollar-in-default claim with infinite maturity, less a claim where you receive a dollar in default conditional on it not occurring prior to \( T \):

\[
G (\omega_t, t; T) = G (\omega_t, t) - e^{-r(T-t)} E^B \left[ G (\omega_T, T) \cdot I_{T \not\leq T} \right]
\]

\textsuperscript{14}The probabilities are previously known, as is the formula the down-and-out binary option in Lemma 3.7.1 (see for example Björk (1998)).
Using a change of probability measure, we can separate the variables within the expectation brackets (see e.g. Geman et al. (1995)).

\[
G(\omega_t, t; T) = G(\omega_t, t) - e^{-r(T-t)}E^P[G(\omega_T, T)] \cdot E^G[I_{T \notin T}]
\]

\[
= G(\omega_t, t) \cdot (1 - Q^G(T \notin T))
\]

### 3.7.2 The Leland Model

The value of the firm

\[
F(\omega_t) = \omega_t + \tau \frac{C}{r} \left[ 1 - \left( \frac{\omega_t}{L} \right)^{-x} \right] - \alpha L \cdot \left( \frac{\omega_t}{L} \right)^{-x}
\]

with

\[
x = \frac{(r - \beta - 0.5\sigma^2) + \sqrt{(r - \beta - 0.5\sigma^2)^2 + 2\sigma^2r}}{\sigma^2}
\]

Value of debt

\[
D(\omega_t) = \frac{C}{r} + \left( (1 - \alpha) L - \frac{C}{r} \right) \left( \frac{\omega_t}{L} \right)^{-x}
\]

The bankruptcy barrier

\[
L = \frac{(1 - \tau)C}{r} \cdot \frac{x}{1 + x}
\]

### 3.7.3 The Leland & Toft Model

The value of the firm is the same as in Leland (1994). The value of debt is given by

\[
D(\omega_t) = \frac{C}{r} + \left( N - \frac{C}{r} \right) \left( 1 - \frac{e^{-rT}}{rT} - I(\omega_t) \right) + \left( (1 - \alpha) L - \frac{C}{r} \right) J(\omega_t)
\]

The bankruptcy barrier

\[
L = \frac{C \left( \frac{A}{rT} - B \right) - \frac{AE}{r} - \frac{\tau Ge}{r}}{1 + \alpha x - (1 - \alpha)B}
\]

where

\[
A = 2ye^{-rT} \phi \left[ y\sigma \sqrt{T} \right] - 2z\phi \left[ z\sigma \sqrt{T} \right]
\]

\[
- \frac{2}{\sigma \sqrt{T}} n \left[ z\sigma \sqrt{T} \right] + \frac{2e^{-rT}}{\sigma \sqrt{T}} n \left[ y\sigma \sqrt{T} \right] + (z - y)
\]
\[
B = - \left( 2z + \frac{2}{z_\sigma^2 Y} \right) \phi \left[ z_\sigma \sqrt{Y} \right] - \frac{2}{\sigma \sqrt{Y}} n \left[ z_\sigma \sqrt{Y} \right] + (z - y) + \frac{1}{z_\sigma^2 Y}
\]

and \( n[\cdot] \) denotes the standard normal density function.

The components of the debt formulae are

\[
I(\omega) = \frac{1}{rY} \left( i(\omega) - e^{-rY} j(\omega) \right)
\]

\[
i(\omega) = \phi [h_1] + (\omega \sigma)^{-2a} \phi [h_2]
\]

\[
j(\omega) = \left( \frac{\omega}{L} \right)^{-y+z} \phi [q_1] + \left( \frac{\omega}{L} \right)^{-y-z} \phi [q_2]
\]

and

\[
J(\omega) = \frac{1}{z_\sigma \sqrt{Y}} \begin{pmatrix}
- \left( \frac{\omega}{Y} \right)^{-a+z} \phi [q_1] q_1 \\
+ \left( \frac{\omega}{Y} \right)^{-a-z} \phi [q_2] q_2
\end{pmatrix}
\]

Finally

\[
q_1 = \frac{-b - z_\sigma^2 Y}{\sigma \sqrt{Y}}
\]

\[
q_2 = \frac{-b + z_\sigma^2 Y}{\sigma \sqrt{Y}}
\]

\[
h_1 = \frac{-b - y_\sigma^2 Y}{\sigma \sqrt{Y}}
\]

\[
h_2 = \frac{-b + y_\sigma^2 Y}{\sigma \sqrt{Y}}
\]

and

\[
y = \frac{r - \beta - 0.5\sigma^2}{\sigma^2}
\]

\[
z = \frac{\sqrt{y^2 \sigma^4 + 2r\sigma^2}}{\sigma^2}
\]

\[
x = y + z
\]

\[
b = \ln \left( \frac{\omega}{L} \right)
\]
3.7.4 The Fan & Sundaresan Model

Given the trigger point for strategic debt service $S$, the value of the firm is

$$ F(\omega_t) = \begin{cases} 
\omega_t + \frac{rC}{r} - \frac{\lambda_+}{\lambda_+ - \lambda_-} \frac{rC}{r} \left( \frac{\omega}{S} \right)^{\lambda_-}, & \text{when } \omega_t > S \\
\omega_t + \frac{\lambda_-}{\lambda_+ - \lambda_-} \frac{rC}{r} \left( \frac{\omega}{S} \right)^{\lambda_-}, & \text{when } \omega_t \leq S
\end{cases} $$

The equity value is

$$ E(\omega_t) = \begin{cases} 
\omega_t - C(1-\tau) + \left[ \frac{C(1-\tau)}{(1-\lambda_-)r} - \frac{\lambda_-}{\lambda_+ - \lambda_-} \frac{\lambda_-}{(1-\lambda_-)r} \frac{rC}{r} \right] \left( \frac{\omega}{S} \right)^{\lambda_-}, & \text{when } \omega_t > S \\
\eta F(\omega_t) - \eta (1 - \alpha) \omega_t, & \text{when } \omega_t \leq S
\end{cases} $$

(3.4)

where $\eta$ denotes bargaining power of bondholders. The trigger point for strategic debt service is

$$ S = \frac{(1 - \tau + \eta \tau)C - \lambda_-}{r} \frac{1}{1 - \lambda_-} \frac{1}{1 - \eta \alpha} $$

and

$$ \lambda_\pm = 0.5 - \frac{(r - \beta)}{\sigma^2} \pm \sqrt{\left[ \frac{(r - \beta)}{\sigma^2} - 0.5 \right]^2 + \frac{4r}{\sigma^2}} $$
TABLE 3.1: LIST OF NOTATION / PARAMETER VALUES

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Notation</th>
<th>Leland</th>
<th>Leland &amp; Toft</th>
<th>Fan &amp; Sundaresan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bond principal / coupon / maturity</td>
<td>$P / c / T$</td>
<td>According to actual contract</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CDS and bond recovery rate</td>
<td>$\psi$</td>
<td>40%</td>
<td>40%</td>
<td>40%</td>
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<tr>
<td>Riskfree rate</td>
<td>$r$</td>
<td>Treasury yields interpolated to match bond maturity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Debt Nominal</td>
<td>$N$</td>
<td>Total liabilities from firm's balance sheet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Debt Coupon</td>
<td>$C$</td>
<td>$r \cdot N$</td>
<td>$r \cdot N$</td>
<td>$r \cdot N$</td>
</tr>
<tr>
<td>Debt Maturity</td>
<td>$T$</td>
<td>$5 / 10$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bargaining power of debtholders</td>
<td>$\eta$</td>
<td></td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>Costs of Financial Distress</td>
<td>$\alpha$</td>
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<td>15%</td>
<td>15%</td>
</tr>
<tr>
<td>Tax rate</td>
<td>$\tau$</td>
<td>20%</td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td>Revenue rate</td>
<td>$\beta$</td>
<td>0% / Weighted average$^1$ / 6%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$^1$The weighted average of the revenue rate is calculated from the balance sheets as

\[
\frac{\text{Interest Expenses}}{\text{Total Liabilities}} \times \text{Leverage} + \frac{\text{Dividend Yield}}{\text{Total Liabilities}} \times (1 - \text{Leverage})
\]

where

\[
\text{Leverage} = \frac{\text{Total Liabilities}}{\text{Total Liabilities} + \text{Market Capital}}
\]
<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Minimum</th>
<th>Maximum</th>
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</thead>
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<tr>
<td>Firm Size (billions of $)</td>
<td>67.9</td>
<td>96.2</td>
<td>2.0</td>
<td>78.4</td>
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<td>Leverage</td>
<td>50%</td>
<td>19%</td>
<td>8%</td>
<td>9%</td>
</tr>
<tr>
<td>SP rating</td>
<td>9.8</td>
<td>4.8</td>
<td>1</td>
<td>27</td>
</tr>
<tr>
<td>Bond transaction size (dollars)</td>
<td>5.9&quot;</td>
<td>20.3&quot;</td>
<td>3000</td>
<td>411&quot;</td>
</tr>
<tr>
<td>Bond issue size (dollars)</td>
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<td>660&quot;</td>
<td>652&quot;</td>
<td>5000&quot;</td>
</tr>
<tr>
<td>Bond age</td>
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<td>3.4</td>
<td>0</td>
<td>15.9</td>
</tr>
<tr>
<td>Bond maturity</td>
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<td>8.6</td>
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<td>98.0</td>
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<tr>
<td>Bond coupon</td>
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**Table 3: Summary statistics - Bond spreads and CDS premia**

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<tr>
<th>Rating</th>
<th>Transactions</th>
<th>Bond Yield spreads relative Treasury curve</th>
<th>Bond Yield spreads relative swap curve</th>
<th>CDS premia</th>
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<td>Stdev</td>
<td>Min</td>
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<td>18</td>
<td>29</td>
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<td>75</td>
<td>28</td>
<td>8.5</td>
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<td>25</td>
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<tr>
<td>A+</td>
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<td>96</td>
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<tr>
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<td>118</td>
<td>43</td>
<td>26</td>
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<tr>
<td>A-</td>
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<td>152</td>
<td>47</td>
<td>64</td>
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<td>34</td>
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<td>44</td>
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<td>163</td>
<td>97</td>
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<tr>
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<td>36</td>
<td>367</td>
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<td>166</td>
<td>134</td>
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<td>194</td>
<td>125</td>
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<td>na</td>
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### Table 3.4: Summary of Firm Specific Estimation Output

#### Panel A: Treasury Reference Curve

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model</th>
<th>Mean</th>
<th>Std.Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asset return</td>
<td>L</td>
<td>30%</td>
<td>12%</td>
<td>6%</td>
<td>90%</td>
</tr>
<tr>
<td></td>
<td>FS</td>
<td>30%</td>
<td>12%</td>
<td>6%</td>
<td>91%</td>
</tr>
<tr>
<td></td>
<td>LT (T=6.76)</td>
<td>23%</td>
<td>11%</td>
<td>6%</td>
<td>73%</td>
</tr>
<tr>
<td>Volatility</td>
<td>L</td>
<td>58.0</td>
<td>81.4</td>
<td>1.0</td>
<td>617.4</td>
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<tr>
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<td>FS</td>
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<td>80.7</td>
<td>1.0</td>
<td>607.8</td>
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<tr>
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<td>64.3</td>
<td>90.4</td>
<td>1.9</td>
<td>720.5</td>
</tr>
<tr>
<td>Default barrier (billion of $)</td>
<td>L</td>
<td>10.7</td>
<td>22.4</td>
<td>0.1</td>
<td>215.4</td>
</tr>
<tr>
<td></td>
<td>FS</td>
<td>11.4</td>
<td>23.6</td>
<td>0.1</td>
<td>226.5</td>
</tr>
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<td>20.8</td>
<td>43.6</td>
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<td>420.6</td>
</tr>
<tr>
<td>Distance to default</td>
<td>L</td>
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<td>0.8</td>
<td>1.0</td>
<td>5.4</td>
</tr>
<tr>
<td></td>
<td>FS</td>
<td>2.7</td>
<td>0.7</td>
<td>1.0</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>LT (T=6.76)</td>
<td>2.8</td>
<td>0.7</td>
<td>1.1</td>
<td>5.5</td>
</tr>
<tr>
<td>Dollar in default year 2 (%)</td>
<td>L</td>
<td>0.8%</td>
<td>2.7%</td>
<td>0.0%</td>
<td>28.8%</td>
</tr>
<tr>
<td></td>
<td>FS</td>
<td>1.3%</td>
<td>3.8%</td>
<td>0.0%</td>
<td>37.9%</td>
</tr>
<tr>
<td></td>
<td>LT (T=6.76)</td>
<td>1.4%</td>
<td>3.3%</td>
<td>0.0%</td>
<td>37.4%</td>
</tr>
<tr>
<td>Dollar in default year 10 (%)</td>
<td>L</td>
<td>12.8%</td>
<td>13.4%</td>
<td>0.0%</td>
<td>79.3%</td>
</tr>
<tr>
<td></td>
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<td>15.1%</td>
<td>14.6%</td>
<td>0.0%</td>
<td>80.6%</td>
</tr>
<tr>
<td></td>
<td>LT (T=6.76)</td>
<td>17.2%</td>
<td>14.0%</td>
<td>0.0%</td>
<td>83.8%</td>
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</table>
Panel B: Swap reference curve

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model</th>
<th>Mean</th>
<th>Std.Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asset return L</td>
<td>29%</td>
<td>12%</td>
<td>7%</td>
<td>85%</td>
<td></td>
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<tr>
<td>volatility FS</td>
<td>29%</td>
<td>12%</td>
<td>7%</td>
<td>86%</td>
<td></td>
</tr>
<tr>
<td>LT (T=6.76)</td>
<td>23%</td>
<td>11%</td>
<td>6%</td>
<td>73%</td>
<td></td>
</tr>
<tr>
<td>Asset value (billion of $) L</td>
<td>59.1</td>
<td>83.4</td>
<td>1.1</td>
<td>643.1</td>
<td></td>
</tr>
<tr>
<td>LT (T=6.76)</td>
<td>58.8</td>
<td>82.8</td>
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<td>635.4</td>
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</tr>
<tr>
<td>Default barrier (billion of $) L</td>
<td>12.0</td>
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<td>0.2</td>
<td>251.4</td>
<td></td>
</tr>
<tr>
<td>LT (T=6.76)</td>
<td>12.8</td>
<td>27.5</td>
<td>0.2</td>
<td>265.6</td>
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<tr>
<td>Distance to default L</td>
<td>2.8</td>
<td>0.8</td>
<td>1.0</td>
<td>5.3</td>
<td></td>
</tr>
<tr>
<td>LT (T=6.76)</td>
<td>2.7</td>
<td>0.7</td>
<td>1.0</td>
<td>5.0</td>
<td></td>
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<tr>
<td>Dollar in default year 2 (%) L</td>
<td>0.7%</td>
<td>2.7%</td>
<td>0.0%</td>
<td>29.7%</td>
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<tr>
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<td>1.3%</td>
<td>3.9%</td>
<td>0.0%</td>
<td>39.8%</td>
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</tr>
<tr>
<td>Dollar in default year 10 (%) L</td>
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<td>12.2%</td>
<td>0.0%</td>
<td>76.5%</td>
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<tr>
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<td>13.5%</td>
<td>0.0%</td>
<td>78.2%</td>
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### Table 5: Asset Volatility Estimates by Rating

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<th></th>
<th>CMT</th>
<th>SWAP</th>
<th>Schaefer &amp; Strebulaev</th>
</tr>
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<tbody>
<tr>
<td>AAA</td>
<td>16%</td>
<td>17%</td>
<td>25%</td>
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<td>AA</td>
<td>29%</td>
<td>29%</td>
<td>22%</td>
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<tr>
<td>A</td>
<td>21%</td>
<td>22%</td>
<td>22%</td>
</tr>
<tr>
<td>BBB</td>
<td>23%</td>
<td>23%</td>
<td>22%</td>
</tr>
<tr>
<td>BB</td>
<td>25%</td>
<td>25%</td>
<td>26%</td>
</tr>
<tr>
<td>B</td>
<td>36%</td>
<td>36%</td>
<td>31%</td>
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<tr>
<td>CCC</td>
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<td>all</td>
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<td>22%</td>
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</table>
Table 3.6: Bond spread and CDS premia estimates: the Leland model

Panel A: Treasury reference curve

<table>
<thead>
<tr>
<th></th>
<th>Market Bond Spreads</th>
<th>Model Bond Spreads</th>
<th>Residual Bond Spreads</th>
<th>Market CDS Premia</th>
<th>Model CDS Premia</th>
<th>Residual CDS Premia</th>
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</thead>
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<td>127</td>
<td>112</td>
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<td>614</td>
<td>914</td>
<td>1000</td>
<td>588</td>
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<tr>
<td>Mean</td>
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<td>82</td>
<td>91</td>
<td>112</td>
<td>69</td>
<td>43</td>
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<td>Std. Dev.</td>
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<td>123</td>
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<td>119</td>
<td>134</td>
<td>124</td>
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<td>70</td>
<td>112</td>
<td>77</td>
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<td>121</td>
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Panel B: Swap reference curve

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<th>Residual Bond Spreads</th>
<th>Market CDS Premia</th>
<th>Model CDS Premia</th>
<th>Residual CDS Premia</th>
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<td></td>
</tr>
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<td>67</td>
<td>112</td>
<td>36</td>
<td>76</td>
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<tr>
<td>Std. Dev.</td>
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<td>70</td>
<td>113</td>
<td>119</td>
<td>66</td>
<td>102</td>
</tr>
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<td>-346</td>
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<td>894</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
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<td>73</td>
<td>38</td>
<td>112</td>
<td>62</td>
<td>50</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>124</td>
<td>117</td>
<td>118</td>
<td>119</td>
<td>126</td>
<td>118</td>
</tr>
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Table 3.7: Bond spread and CDS premia estimates: the Fan & Sundaresan model

Panel A: Treasury reference curve

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<th>Residual Bond Spreads</th>
<th>Market CDS Premia</th>
<th>Model CDS Premia</th>
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Panel B: Swap reference curve

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### Table 3.8: Bond spread and CDS premia estimates: the Leland & Toft model

**Panel A: Treasury reference curve**

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<th>Market Bond Spreads</th>
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<th>Market Bond CDS Spreads</th>
<th>Model Bond CDS Spreads</th>
<th>Residual Bond CDS Spreads</th>
<th>Market Bond CDS Premia</th>
<th>Model Bond CDS Premia</th>
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**Panel B: Corporate reference curve**

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Panel B: Swap reference curve

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<th>Model Bond Premia</th>
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TABLE 3.9: RESIDUAL ANALYSIS (WEEKLY AVERAGE TIME SERIES)

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<th>(A) Bond Residual Spread (CMT)</th>
<th>(B) Bond Residual Spread (SWAP)</th>
<th>(C) CDS Residual Premium (CMT)</th>
<th>(D) CDS Residual Premium (SWAP)</th>
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<tr>
<td></td>
<td>Coef.  Std. Err.  t  P&gt;</td>
<td>t</td>
<td>95% Conf. Interval</td>
<td>Coef.  Std. Err.  t  P&gt;</td>
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<tr>
<td>CMT 5Y</td>
<td>-7.466  10.004  -0.75  0.456  -27.18  12.25</td>
<td>-11.57  9.768  -1.18  0.237  -30.82  7.68</td>
<td>-15.54  10.034  -1.55  0.123  -35.32  4.23</td>
<td>-12.65  9.797  -1.29  0.198  -31.96  6.661</td>
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<tr>
<td>Default Prem.</td>
<td>0.6447  2.91E-01  2.22  0.028  0.071  1.22</td>
<td>0.6152  0.295  2.08  0.038  0.033  1.197</td>
<td>0.156  0.311  0.5  0.615  -0.456  0.770</td>
<td>0.156  0.311  0.5  0.615  -0.456  0.770</td>
</tr>
<tr>
<td>Swap 5Y</td>
<td>-0.1047  0.339  -0.31  0.758  -0.774  0.5648</td>
<td>-0.5022  3.45E-01  -1.45E+00  0.147  -1.183  1.79E-01</td>
<td>-0.575  0.366  -1.57  0.118  -1.296  0.146</td>
<td>-0.575  0.366  -1.57  0.118  -1.296  0.146</td>
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<td>SP500 Return</td>
<td>311.9  99.243  3.14  0.002  116.3  507.5</td>
<td>336.5  99.034  3.4  0.001  141.31  531.75</td>
<td>286.9  89.507  3.21  0.002  110.51  463.39</td>
<td>286.9  89.507  3.21  0.002  110.51  463.39</td>
</tr>
<tr>
<td>VIX</td>
<td>0.4234  1.451  0.29  0.771  -2.436  3.283</td>
<td>0.5847  1.430  0.41  0.683  -2.235  3.404</td>
<td>0.742  1.380  0.52  0.606  -2.008  3.432</td>
<td>0.712  1.380  0.52  0.606  -2.008  3.432</td>
</tr>
<tr>
<td>Constant</td>
<td>20.34  91.208  0.22  0.824  -159.44  200.13</td>
<td>20.34  89.814  0.73  0.468  -111.7  242.37</td>
<td>-0.1171  89.068  0  0.999  -175.69  230.79</td>
<td>56.85  88.238  0.64  0.52  -117.07  230.79</td>
</tr>
</tbody>
</table>

R-squared = 0.1450

R-squared = 0.2382

R-squared = 0.1791

R-squared = 0.1577
### TABLE 3.10: RESIDUAL ANALYSIS (CROSS SECTION)

#### (A) Bond Residual Spread (CMT)

| Coef.  | Std. Err. | t     | P>|t|  | [95% Conf. Interval] |
|--------|-----------|-------|-----|-----------------|
| Coupon | 14.84     | 8.859 | 1.68| 0.097 | -2.716 | 32.401 |
| Trans Size | -4.51e-07 | 4.75e-07 | -0.95 | 0.345 | -1.39e-06 | 4.91e-07 |
| Issue Amount | -0.00004 | 0.00035 | -1.14 | 0.255 | -0.0011 | 0.0003 |
| Firm Size | -0.00009 | 0.00035 | -0.44 | 0.662 | 0.0003 | 0.00049 |
| Bond Maturity | 0.0522 | 3.155 | 0.18 | 0.861 | 5.7012 | 6.805 |
| On-the-run | 66.448 | 57.115 | 1.16 | 0.247 | -46.752 | 179.648 |
| Constant | -41.961 | 88.585 | -0.47 | 0.637 | 217.53 | 133.61 |

R-squared = 0.0189

#### (B) Bond Residual Spread (SWAP)

| Coef.  | Std. Err. | t     | P>|t|  | [95% Conf. Interval] |
|--------|-----------|-------|-----|-----------------|
| Coupon | 12.741 | 9.0080 | 1.41 | 0.160 | -5.11 | 30.595 |
| Trans Size | -5.04e-07 | 4.71e-07 | -1.07 | 0.287 | -1.44e-06 | 4.30e-07 |
| Issue Amount | -0.00004 | 0.00035 | -1.18 | 0.242 | -0.0011 | 0.00029 |
| Firm Size | -0.00009 | 0.00021 | 0.41 | 0.679 | -0.0003 | 0.0005 |
| Bond Maturity | 2.0089 | 3.1926 | 0.63 | 0.531 | -4.319 | 8.337 |
| On-the-run | 59.647 | 56.149 | 1.07 | 0.299 | -51.438 | 171.13 |
| Constant | -93.394 | 89.442 | -1.04 | 0.299 | -270.66 | 83.87 |

R-squared = 0.0231

#### (C) CDS Residual Premium (CMT)

| Coef.  | Std. Err. | t     | P>|t|  | [95% Conf. Interval] |
|--------|-----------|-------|-----|-----------------|
| Coupon | 11.580 | 13.599 | 0.85 | 0.396 | -15.3733 | 38.535 |
| Trans Size | 1.02e-06 | 6.60e-07 | 0.15 | 0.126 | -2.33e-06 | 0.000 |
| Issue Amount | -0.00025 | 0.0005 | -0.51 | 0.610 | -0.000125 | 0.000 |
| Firm Size | 0.00153 | 0.0029 | 0.53 | 0.596 | -0.000419 | 0.001 |
| Bond Maturity | 2.9038 | 3.582 | 0.81 | 0.419 | -4.1964 | 10.004 |
| On-the-run | 78.7505 | 68.619 | 1.15 | 0.254 | -57.270 | 214.732 |
| Constant | -112.393 | 120.99 | -0.93 | 0.355 | -352.21 | 127.424 |

R-squared = 0.0227

#### (D) CDS Residual Premium (SWAP)

| Coef.  | Std. Err. | t     | P>|t|  | [95% Conf. Interval] |
|--------|-----------|-------|-----|-----------------|
| Coupon | 13.713 | 13.357 | 1.03 | 0.307 | -12.759 | 40.187 |
| Trans Size | -9.73e-07 | 6.50e-07 | -1.50 | 0.137 | -2.26e-06 | 0.000 |
| Issue Amount | -0.00022 | 0.00048 | -0.45 | 0.653 | -0.000119 | 0.000 |
| Firm Size | 0.0012 | 0.0028 | 0.44 | 0.660 | -0.00044 | 0.001 |
| Bond Maturity | 3.0564 | 3.607 | 0.85 | 0.399 | -4.9027 | 10.206 |
| On-the-run | 87.500 | 65.156 | 1.35 | 0.180 | -41.237 | 217.038 |
| Constant | -129.073 | 120.27 | -1.07 | 0.286 | -367.456 | 109.308 |

R-squared = 0.0258
Figure 3.1: Summary view of estimation output. The uppermost left panel plots the weekly averaged asset volatility across firms. The remaining panels plot the asset value, firm leverage and market capitalizations respectively.
Figure 3.3: Difference between Bond and CDS residuals. The upper panel plots this difference for CMT based residuals, in comparison with 5 and 10 year swap spreads. The lower panel plots the same measure based on the swap curve.
Figure 1: **Figure 3.2: Summary of pricing output.** The upper (lower) two panels represent results for CDS (bond) pricing. The left panels are based on the CMT curve as benchmarks whereas the right ones use the swap curve.
Chapter 4

What Risks Do Corporate Bond Put Features Insure Against?

4.1 Introduction

Putable bonds give their owners the right to sell, or put, their bond to the issuer prior to the bond’s maturity date. Research reveals that corporate bond prices are influenced by a number of risk factors, the most important of which are likely interest rate risk, default risk, and illiquidity\(^1\). The option to put back the bond to the issuers appears to be designed to provide insurance against all three. While callable and convertible bonds have well-understood embedded option features, this paper constitutes, to the best of our knowledge, the first empirical study of putable bond valuation.\(^2\)

We study a sample of more than a thousand putable bond transactions together with a control sample of prices for regular bonds issued by the same corporations. We perform a linear regression analysis on the relationship be-

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\(^1\)See Huang & Huang (2003) and Elton et al. (2001).

\(^2\)An interesting related study can be found in David (2001) which develops a theoretical model of the strategic value of holding putable debt when a firm experiences a liquidity crisis.
tween putable and regular bond yield spreads and key default, liquidity and interest rate proxies suggested by economic theory and previous empirical research.\(^3\) We find that the estimated coefficients, for both putable and regular bonds, of the three classes of proxies are not only consistent with theory, but also statistically and economically significant. Interestingly, we find that, in comparison to regular bond spreads, putable bond spreads are statistically more significant but economically less sensitive to those proxies. This suggests that put options embedded in corporate bonds help to reduce bondholders' exposures to those risks.

The first main focus of this article is to analyze which risks put options insure against. Intuitively, a putable bond is simply a regular bond with a put option attached. The price of a putable bond can be split into the price of a regular bond and the price of a put option. We therefore proxy the market value of the put option by the difference in yield spreads on a given day between the regular and putable bonds issued by the same corporation\(^4\). We find that the put option does significantly hedge against all three risks. The reduction in corporate bond yield spread due to the presence of a put is, on average, just over 40% of the yield spread. By means of regression analysis we show that the put option value (as measured by the spread reduction) is related to proxies for default, interest rate, and marketability risk.

We show that the value of a put option is positively and significantly correlated to credit proxies, including firm leverage, equity volatility, and Moody's default premium. This suggests that their value increases as default become more likely. In addition, analysis on illiquidity proxies shows that a put option is less valuable for the bonds issued by relatively large firms. A larger firm is likely to enjoy the attention of a larger number of investors and to enjoy

\(^3\)See Collin-Dufresne et al. (2001), Campbell & Taksler (2002), and Ericsson et al. (2004).

\(^4\)The market value of put options is adjusted for properties' differences, including coupons and maturities, between the matched regular and putable bonds in sample.
better marketability of its securities. Furthermore, the value of a put option increases when market liquidity, as measured by the Pastor-Stambaugh Index, deteriorates. The risk-free rate shows a strong and positive correlation. This confirms the intuition that the puts are more likely to be exercised when interest rates are high, which, in turn, increases their value.

The market value of the put is significantly influenced by contractual features. Our results indicate that the value of a put increases as the time to the earliest exercise date decreases. Moreover, its value increases with the remaining life of the put. Not surprisingly, a put option is more valuable the lower the bond price is relative to par. A putable bond with more frequent put dates is more valuable.

Given that we have established that put values are related to the conjectured risks, we proceed to measure that proportion of the put option value that can be attributed to insurance against those risk factors, respectively. To do this, we require a model that prices putable bonds. Accordingly, we develop a bivariate lattice model that simultaneously captures correlated default and interest rate risk. Our model is closely related to Das & Sundaram (2006). The authors develop an integrated model for pricing securities that are subject to equity risk, interest rate risk, and default risk simultaneously. Their approach is based on observed equity prices and interest rates. A constant default intensity is extracted by calibrating the model to the observed market prices of derivatives contingent on equity prices. In our model, we follow a different approach where the key sources of uncertainty are the value of a firm's assets and term structure fluctuations. We draw on recent developments in the literature on structural credit risk models and their joint model of term structure and default risk to design a practicable valuation framework for corporate putable bonds. This involves, in a first step, the estimation of corporate asset values, volatilities, and the historical correlation between as-
set values and interest rates (for which we rely on the Leland & Toft (1996) model, and maximum likelihood estimation). In a second step, we construct a recombining lattice HJM term structure model.

Our method offers a fast and accurate approach for the valuation of corporate bonds with embedded options. The model is flexible enough to be applicable to both convertible and callable bonds.

Applying the model to price regular and putable bonds, we illustrate that most of the reduction in the putable bond spread (about 60%) is due to a decrease in the default component of the spread. A third of the reduction is due to mitigated term structure risk. The smallest fraction (7%) represents a reduction in the illiquidity component of the bond spread.

Our result that the dominant source of spread reduction is due to default risk may seem somewhat surprising given that there should be significant "counterparty" risk – when default is imminent the firm may not be able to honor the insurance it has implicitly written. Consistent with this, we find that the reduction due to default risk at first increases as credit quality deteriorates, but only up to a point. As bonds approach very low rating categories, the relative spreads' reduction decreases. Thus, we do find that the put option value is significantly reduced for firms at the brink of financial distress.

The remainder of this paper is structured as follows. Section 2 introduces the theoretical frameworks, and data and regression analyses on put options. Section 3 describes the bivariate lattice model. In Section 4, the value of put options as insurance against various risk factors is decomposed. Finally, Section 5 concludes.
4.2 Analytical framework

This article examines putable bonds and the put options with variables as suggested by the theory of structural-form credit risk models. This literature starts with the seminal work of Black & Scholes (1973) and Merton (1974). Although their basic model has been later extended in various ways, structural models share a number of common determinants of default risk. Leverage is a critical factor - a firm with higher leverages tends to have higher likelihood of default in comparison to a firm with otherwise identical characteristics. The underlying asset return volatility is another essential determinant of default probability, because a corporate bond can be seen as a default risk-free bond plus a short position on the put option. Volatility affects the value of the put option. Moreover, structural models predict that (constant) risk-free interest rates negatively influence default risk. A theoretical explanation for this relationship is that, under the risk-neutral measure, the firm's underlying asset value increases at a faster speed; this, in turn, reduces the probability of the asset value hitting the default barrier.

In comparison to regular corporate bonds, putable corporate bonds allow bond holders to sell the bonds back to the issuers prior to the bond’s maturity date. Therefore, the value of a putable bond should be subject the same risk factors, because the option appears to provide partial insurance against the risks, given that the bond indenture stipulates when and how the bond can

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6 Studies that explicitly model stochastic riskfree interest rate show the same result. Those includes Longstaff & Schwartz (1995) and Collin-Dufresne & Goldstein (2001).
be put throughout the life of a putable bond. Accordingly, the yield spread of the putable bond as well as the market value of the put option should be determined by the leverage ratio of the underlying firm, the volatility of the firm asset return, the riskless spot rates, and the maturity of the individual bond. The latter factor is suggested by Leland & Toft (1996). We denote the leverage of the firm \( i \) at time \( t \) as \( \text{lev}_{i,t} \), the asset volatility as \( \sigma_{i,t} \), and the bond maturity as \( \text{MAT}_{i,t} \). We define the risk-free rate variable to be the 5-year yield, denoted as \( r^5 \). This choice is motivated by previous empirical findings that the unobservable short rate, the base of a theoretical model, can be determined by a number of factors. One factor is the yield of longer maturities' default-free bonds. For parsimony, we therefore opt for this choice of proxy. Other longer proxies are taken for robustness analysis but our result seems unaffected by the choice of the maturities of risk-free rates in our data sample.

On the other hand, empirical research shows that a corporate bond spread contains not only credit risk premium, but also compensation for liquidity and tax effects\(^7\). For this reason, it seems very naive to limit to the theoretical induced base regressors. We augment our regression analysis by including factors suggested by previous empirical studies. Following Collin-Dufresne et al. (2001), Campbell & Taksler (2002), and Ericsson et al. (2004), we study corporate bond and credit derivative data. We add a number of other explanatory variables that are used to represent a significant proportion of the yield spreads of regular corporate bonds. Then, we investigate the importance of those factors in determining the credit spreads of putable bonds and the value of put options attached. For the empirical credit risk factors, we add the return of the S&P 500, denoted by \( S&P_t \), used in Collin-Dufresne et al. (2001) to proxy for the overall state of the economy. The Moody's default premium is denoted

\(^7\)See Elton et al. (2001) and Longstaff et al. (2005).
by $MDP_t$; it is supposed to capture the default risk premia in the corporate bond market that is above the expected loss fraction of the spread, and not captured by the previous theoretical factors mentioned. The S&P ratings of the underlying firms are denoted by $SPR_{i,t}$, which captures the overall riskiness of the firm. We are conscious that the rating is correlated to those theoretical factors by construction, and there will be collinearity. Nevertheless, we are interested in the additional explanatory power that the rating can provide over and above the other factors. Following Collin-Dufresne et al. (2001), we use the option-implied volatility based on the S&P 100 Index options denoted by $VIX_t$.

With respect to the empirical liquidity factors, we add the bond age denoted by $AGE_{i,t}$. Older Bonds should be expected to be less liquid—this analogy is extensively documented in the default-free bond market. Another liquidity factor is the firm size denoted by $SIZE_{i,t}$. We expect firms of a large capital size to attract a greater number of investors and to enjoy better marketability of their securities. Furthermore, we use the Pastor & Stambaugh Index, denoted by $PSI_t$, as a general measure of market liquidity, mindful that this measure captures the liquidity in the equity market. However, a significant degree of integration between the equity and the corporate bonds market implies that we should proxy this measure for the bond market liquidity. We use coupon rates, $CPN_i$, as our empirical proxy for tax effects as suggested in Longstaff et al. (2005).

The regressions suggested by the previously enumerated theory and empirical studies consist therefore of regressing putable bond spreads, $PS_{i,t}$, and regular bond spreads, $RS_{i,t}$, on the independent variables described above. We
also add a constant to these regressions, which yields

$$PS_{i,t} = \alpha_i + \beta_{i,1}^{PS} \text{lev}_{i,t} + \beta_{i,2}^{PS} \sigma_{i,t} + \beta_{i,3}^{PS} \text{MAT}_{i,t} + \beta_{i,4}^{PS} r^5_{i,t} + \beta_{i,5}^{PS} \text{S&P}_t$$

$$+ \beta_{i,6}^{PS} \text{MDP}_t + \beta_{i,7}^{PS} \text{SPR}_{i,t} + \beta_{i,8}^{PS} \text{VIX}_t + \beta_{i,9}^{PS} \text{AGE}_{i,t} + \beta_{i,10}^{PS} \text{SIZE}_{i,t}$$

$$+ \beta_{i,11}^{PS} \text{PSI}_t + \beta_{i,12}^{PS} \text{CPN}_i + \varepsilon_{i,t} \quad (4.1)$$

$$RS_{i,t} = \alpha_i + \beta_{i,1}^{RS} \text{lev}_{i,t} + \beta_{i,2}^{RS} \sigma_{i,t} + \beta_{i,3}^{RS} \text{MAT}_{i,t} + \beta_{i,4}^{RS} r^5_{i,t} + \beta_{i,5}^{RS} \text{S&P}_t$$

$$+ \beta_{i,6}^{RS} \text{MDP}_t + \beta_{i,7}^{RS} \text{SPR}_{i,t} + \beta_{i,8}^{RS} \text{VIX}_t + \beta_{i,9}^{RS} \text{AGE}_{i,t} + \beta_{i,10}^{RS} \text{SIZE}_{i,t}$$

$$+ \beta_{i,11}^{RS} \text{PSI}_t + \beta_{i,12}^{RS} \text{CPN}_i + \varepsilon_{i,t} \quad (4.2)$$

Regarding the analysis of the put option value as measured by the spread reduction in the putable spreads, we regress the put option value, $PV_{i,t}$, on some variables described above. We discard the bond-specific factors such as maturity, age and coupon rates because the putable and the regular bonds do not share the same features in general. Indeed, including these factors will give a misleading result. The following regression ensues:

$$PV_{i,t} = \alpha_i + \beta_{i,1}^{PV} \text{lev}_{i,t} + \beta_{i,2}^{PV} \sigma_{i,t} + \beta_{i,3}^{PV} r^5_{i,t} + \beta_{i,4}^{PV} \text{S&P}_t + \beta_{i,5}^{PV} \text{MDP}_t$$

$$+ \beta_{i,6}^{PV} \text{VIX}_t + \beta_{i,7}^{PV} \text{SIZE}_{i,t} + \beta_{i,8}^{PV} \text{PSI}_t + \varepsilon_{i,t} \quad (4.3)$$

### 4.3 Data

We use the following data for our estimation: firm market equity values, balance sheet information, and term structure of swap rates. Daily equity values are obtained from CRSP. Quarterly firm balance sheet data are taken from COMPUSTAT. Swap rates are acquired from DATASTREAM.

Our bond transaction data are sourced from the National Association of Insurance Commissioners (NAIC). Bond issue- and issuer-related descriptive
data are obtained from the Fixed Investment Securities Database (FISD). The majority of transactions in the NAIC database take place between 1995 and 2004.

We adopt rigorous data cleaning measures in order to improve the reliability of the bond transaction data. Bond transactions with counterparty names other than insurance companies and Health Maintenance Organizations (HMOs) are removed. We restrict our sample to fixed coupon rate USD denominated bonds with issuers in the industrial sector. Furthermore, we eliminate bond issues with option features other than putables. Asset-backed issues, and bonds with sinking funds or credit enhancements were also removed to ensure bond prices in the sample truly reflect the underlying credit quality of issuers. The third step involves selecting bonds for which we have issuers' complete and reliable equity data as well as accounting information.

In total, 57 firms have both the transactions of putable and regular bonds in NAIC databases. When we take an intersection of the putable and regular bond data, while requiring the time difference between the putable and regular bond transactions to fall within a week, we are left with 1039 pairs from 45 distinct entities.

Table 4.1 shows the descriptive statistics of issuing companies, putable bonds, and regular bonds. In Table 4.1, we see that firm sizes vary from 1.6 billion to 469 billion with an average of 52 billion dollars. Bond issuers' S&P credit ratings range between AA and CCC, while the majority lie between BBB+ and BBB. The average regular bond issue size is 324 million dollars. The average regular bond transaction size is approximately 2.65 million dollars. In comparison, putable bonds have a smaller average transaction size of 0.33 million dollars, and a smaller average issue size of 270 million dollars. On average, regular bonds are 4.3 years of age, and have 15 years remaining to maturity. Putable bonds are, on average, 5 years old but have a much longer
time to maturity of 26.3 years. The average coupon rates of putable bonds, 7.33%, is almost the same compared to that of regular bonds of 7.25%.

[insert Table 4.1]

The leverage of a firm is defined as

\[
\text{Lev} = \frac{\text{Book Value Of Debt}}{\text{Market Value Total Equity} + \text{Book Value Of Debt}}
\]

where the market value of equity is obtained from CRSP. The book value of debt and the market value of preferred equity data are acquired from COMPUSTAT. Since the balance sheet information is only available at quarterly level, we transfer them into daily data through linear interpolation.

Equity volatility for each firm (for every transaction) is computed using a moving window of 250 daily returns obtained from CRSP. That the asset return volatility is estimated using MLE will be covered in more detail in the Leland & Toft estimation subsection.

To obtain swap rates, we collect daily data of several maturities of coupon-paying swap rates from DATASTREAM. Term structures of swap rates are constructed using polynomial spline, and then bootstrapped to obtain the term structures of zero swap curves. We use the 5-year maturity for regression purposes, and check the robustness of our maturity choices using longer maturities. In addition, different but appropriate risk-free benchmarks are employed. The US constant maturity Treasury yields are computed using the most actively traded (on-the-run) issues of different maturities.

[insert Table 4.2]

Moody’s default premium represents default risk in general. It is computed as Moody’s Baa index spreads minus Aaa index spreads, which has a mean of
86 basis points for the transaction days in our sample. Another default proxy, VIX, comprises the option-implied volatility index acquired from CBOE, and has an average of 23% in a range of 11% and 50%. On average, the daily equally weighted S&P 500 returns are 0.11%. We use Pastor & Stambaugh level\(^8\) from CRSP as a proxy for market liquidity, which has a mean of 0.033 and volatility of 0.068. The average 5-year swap rate in our sample is 4.93%.

### 4.3.1 Regression analysis

Because the data set has a cross-sectional as well as a time-series dimension, several aspects of the relationship between the independent variables and the yield spreads of putable bonds and regular bonds can be investigated. Time-series correlations indicate how spreads change for a given company as the risk factors change over time. Cross-sectional correlations illustrate how yield spreads differ across companies due to differences in various factors. The regression method adopted fits panel data regression models: it can fit fixed-effects (within), between-effects, and random-effects (mixed) models as well as population-averaged models. Regressions are run as random effects GLS with an AR(1) error structure, and use a method developed by Baltagi & Wu (1999) to adjust for the unbalanced nature of the data panel.

**Analysis on put bond and regular bond yield spread**

Table 4.3(A) and 4.3(B) report the results of in-depth regression analysis on market putable bond spreads and regular bond spreads. The independent variables include a set of proxies for credit risk, liquidity risk, tax component,

\(^8\)Pastor & Stambaugh level provides a measure of equity market liquidity. Given the partial integration between the equity and fixed income markets, the measure should also be able to capture the liquidity in corporate bond markets. Therefore, as a proxy for market liquidity measures, we choose the closest (monthly) Pastor & Stambaugh levels to our transaction dates. For details of the index, please see the original paper of Pastor & Stambaugh (2003).
and interest rate risk. To proxy credit risk, we use firm leverages, equity return volatilities, S&P ratings, Moody's default premia, and S&P 500 returns. Firm sizes, bond ages, bond maturities, and Pastor-Stambaugh index levels (pslevel) are used for liquidity proxies. Bond coupon rates present the tax effects. 5-year Treasury rates are used for interest rate risk parameters.

[insert Table 4.3(A)]

For putable bond spreads, as reported in Table 4.3(A), firm leverage, equity volatility and VIX are significant at 5% level, and the S&P 500 return is significant at a 10% level. As expected, the bond spreads are positively correlated to all dependent credit risk variables. Amongst illiquidity variables, pslevel is significant at 5% level. Putable bond spreads are positively related to age and maturity, and negatively to firm size and pslevel. A higher coupon tends to increase bond spreads. This is consistent with the tax effect suggested by Elton et al. (2001). Higher coupons exacerbate the differential taxation of corporate bonds and swaps. In addition, bond spreads are strongly and negatively related to interest rates.

[insert Table 4.3(B)]

Similar results are observed for regular bond spreads. It seems that both putable and regular corporate bond spreads contain compensation to credit, liquidity and interest risks. Interestingly, we find putable bond spreads to be statistically more significant but economically less sensitive to those proxies compared to regular bond spreads. This suggests that the put options embedded in corporate bonds help to reduce bondholders' exposures to those risks.
Analysis on put option value

We use the difference between the market spreads of the matched regular bonds and putable bonds to represent the values of the put options. It is recognized that this measure is contaminated by the different properties between putable and regular bonds. These properties include maturity and coupon rates. In the next subsection, we will show how we quantitatively separate the feature differences in the option values.

The average difference between regular and putable bond spreads is 49 basis points. Table 4.4 reports the results of the regression analysis on put options. The latter are positively and significantly correlated to credit proxies, including firm leverage, equity sigma, and Moody's default premium. This suggests that put option values increase as corporate bonds become more likely to default.

[insert Table 4.4]

The values of put options are negatively correlated to the illiquidity proxies - firm size and pslevel. This implies that the put options are less valuable for the bonds issued by firms of relatively larger size. A large-sized firm is able to attract a larger number of investors and enjoys better marketability of its securities. Therefore, the put options are less valuable as insurance against illiquidity. In addition, that the values of put options increase as market liquidity drops in general is reflected by the negative and significant sign on the Pastor & Stambaugh Index. The risk-free rate shows a strong and positive correlation. This confirms our intuition that put options are more likely to be exercised when interest rates are high, which, in turn, increases their values.

In the next step, we examine the impact of the features of the putable bonds on the values of the embedded options. We use the following parameters: the number of dates to the last scheduled put date (DLP), the number of dates to the first put date (DFP), ratio of the number of outstanding put dates to
maturity of the bond \((NPM)\), ratio of the number of the dates to the first put date to maturity \((FTM)\), and a dummy variable for in-the-money \((ITM)\). Default and liquidity proxies are included as control variables.

\[
P Vi,t \, = \, \alpha + \beta_{i,1} DP_{i,t} + \beta_{i,2} DFP_{i,t} + \beta_{i,3} NPM_{i,t} + \beta_{i,4} FTM_{i,t} + \beta_{i,5} ITM_{i,t} + \beta_{i,6} S P R_{i,t} + \beta_{i,7} M D P_{t} + \beta_{i,8} V I X_{t} + \beta_{i,9} S I Z E_{i,t} + \beta_{i,10} P S I_{t} + \epsilon_{i,t}.
\]

Table 4.5 reports the results of the regression analysis. Dates to first put, dates to last put, and in-the-money variables are statistically significant. The value of a put option increases as the time to the earliest put exercise date approaches. The value increases when there is longer time between the transaction date and the latest put date, confirming the intuition that a put option is more valuable when the option is in the money. The ratio of numbers of outstanding put dates to maturity shows a positive coefficient, implying that, by controlling for maturity, a putable bond with a more frequent put schedule enjoys a relatively higher value. The result is almost statistically significant at 10% level.

Figure 4.1 provides additional evidence that the values of the put options are affected by issuing firms' credit quality and market liquidity. We subgroup our market put option values by issuing firms' credit ratings and market liquidity conditions. It is observable that the values of the put options increase as firms' credit ratings deteriorate until \(BBB\), after which they decrease as firms become increasingly default riskier. The result confirms that put options are used to insure against default risk. However, when an issuing firm is close to bankruptcy, the put options are rendered less valuable by the reduced exercisibility - the issuers are likely to be sent into bankruptcy when putable
bonds are sold back. In addition, we observe that the values of put options generally increase as market liquidity, signaled by the Pastor-Stambaugh Index, decreases. This is consistent with the regression analysis that put options become more valuable when liquidity is relatively low.

[insert Figure 4.1]

We find that put options embedded in corporate bonds contain insurance against default risk, illiquidity risk, and interest rate risk. It is important to decompose the put options and quantify the proportion of the insurance against each individual risk so that meaningful implications for security selection and portfolio risk management may be provided. We proceed to decompose the values of put options in the next subsection. Previous studies have focused on the valuation of corporate bonds. However, their models are suitable for pricing corporate bonds with embedded options, and do not provide the flexibility to decompose the value of the options. Our method offers a fast and accurate approach for the valuation of corporate bonds with embedded features as well as an efficient alternative to Monte-Carlo simulation implementation.

4.4 The model

We develop a bivariate lattice model in which we model the joint risk-neutral process of the asset value and the forward interest rate curve. Our model takes into account the equity-implied correlation between interest rate and asset values. The model combines two binomial trees: the term structure tree, and the asset value tree. Whereas the first tree captures the term structure fluctuation of short rates, the second tree models the firm default process through the evolution of firm assets.

The bivariate lattice model is constructed in the following four steps:
1. Build risk-free rate binomial tree using HJM model.

2. Estimate initial asset value $V_0$, asset return volatility $\sigma_V$, and default barrier $V_b$ using the Leland & Toft (1996) model. In addition, we estimate the correlation between the asset value and the risk-free rate in the maximum likelihood estimation.

3. Construct asset value (default process) binomial tree.

4. Combine the risk-free rate tree and the asset value tree, while imposing recombining conditions.

4.4.1 The term structure model

Our construction of a risk-free tree is based on the discrete-time form of the HJM model (see Heath et al. (1990) and Heath et al. (1992)). The HJM framework uses forward rates and the term structure of forward rate volatilities as inputs to construct the evolution of short rates. For any given pair of time-points $(t, T)$ with $0 \leq t \leq T$, let $f(t, T)$ denote the forward rate on default-free bonds applicable to the period $(T, T + h)$. In other words, $f(t, T)$ is the rate as viewed from time $t$ for a default-free loan transaction over the interval $(T, T+h)$. All interest rates in the model are expressed in continuously compounded terms. When $t = T$, the rate $f(t; t)$ is called the short rate, and denoted by $r(t)$. The forward rate curve is assumed to follow this stochastic process:

$$f(t + h, T) = f(t, T) + \alpha(t, T)h + \sigma(t, T)X_f\sqrt{h}, \quad (4.5)$$

where $X_f$ is a standard Brownian motion, and $\alpha(t, T)$ and $\sigma(t, T)$ are $\mathcal{F}_t$-adapted processes for all $T > t$. The variable $h$ is the length of a single period.
Extensive algebra leads to a recursive expression which relates the risk-neutral drifts $\alpha$ to the volatilities $\sigma$ at each time. Given the risk-neutral dynamics of forward rates, the no-arbitrage value of $\alpha(t, T)$ can be written as:

$$
\alpha(t, s) = \sigma(t, s)^T \sum_{i=1}^{s-t} \sigma(t, t + ih)
$$

where $\sigma(t, t + ih)$ is the volatility of the forward rate between time $t$ and $t + ih$. Note that our modeling of the interest rate tree takes into account the various volatilities of forward rates.

### 4.4.2 The asset value model

We assume that, on any transaction date $t$, the risk-neutral discrete-time asset value is modeled as follows:

$$
\ln \left[ \frac{V(t+h)}{V(t)} \right] = r(t) h + \sigma_V X_V(t) \sqrt{h},
$$

where $\sigma_V$ is the asset return volatility. The random variable $X_V(t)$ takes values of $\{-1, +1\}$.

Under this specification, a probability measure is chosen such that the 1-period expected return of asset value is set to equal $r(t) h$, and the variance of return is $\sigma_V^2 h$. Since the same numeraire (the money market account) is also used in the valuation of bonds, we generate a lattice that is arbitrage free in both the bond and asset value markets.

As an asset value evolves in time, default occurs when the asset value hits, for the first time, the default barrier; the latter is endogenously determined ex post optimal to the value of equity. Upon default, corporate bondholders receive the face value of bonds that they own multiplied by the recovery rate.
4.4.3 The joint process

In this final step, we combine the two processes for the term structure and the asset value introduced above in a bivariate lattice. As illustrated in Figure 4.2, a bivariate lattice has a shape of pyramid. $R$ and $V$ denote the short interest rate and asset value (implied from the Leland and Toft model), respectively, at time $t$. Note that the superscripts $u$ and $d$ on $R$, the interest rate dimension, stand for upper node and lower node, respectively. But, for $V$, the asset value dimension, $u$ and $d$ represent the increments.

![insert Figure 4.2]

The construction of the lattice should satisfy two conditions. The first condition is that the tree recombines. Secondly, the probabilities of the joint process fit the correlation between the asset return and the term structure to the empirical correlation denoted by $\rho$. From every node on the lattice, we observe four departing branches. The corresponding probabilities are those of the realization of $X_f$ and $X_v$, which are embedded in the forward rate and asset value processes, respectively.

\[
\begin{array}{ccc}
X_f & X_v & RN \text{ probability} \\
1 & 1 & \frac{1}{4} (1 + m_1) \\
1 & -1 & \frac{1}{4} (1 - m_1) \\
-1 & 1 & \frac{1}{4} (1 + m_2) \\
-1 & -1 & \frac{1}{4} (1 - m_2)
\end{array}
\]

where $m_1$ and $m_2$ are parameters, whose values will later be determined.

For the HJM model to be recombining, two conditions need to be satisfied: $E(X_f) = 0$ and $Var(X_f) = 1$.

\[
E[X_f] = \frac{1}{4} [(1 + m_1) + (1 - m_1) - (1 + m_2) - (1 - m_2)] = 0,
\]

\[(4.8)\]
and

\[ \text{var}(X_f) = E \left[ (X_f - E[X_f])^2 \right] = E \left[ (X_f)^2 \right] = 1. \] (4.9)

Let us turn our attention to the other dimension of the lattice - the asset value process. For that tree to be recombining, it is essential that the drift of the asset value process is zero. Therefore, the stochastic process for asset value in equation (4.7) becomes

\[
\ln \left[ \frac{V(t+h)}{V(t)} \right] = \sigma V \times X_V(t) \sqrt{h}. \tag{4.10}
\]

The mean and the variance of the random variable \( X_V \) in the asset value process are

\[
E[X_V] = \frac{1}{4} \left[ (1 + m_1) + (1 + m_2) - (1 - m_1) - (1 - m_2) \right] = \frac{m_1 + m_2}{2}, \tag{4.11}
\]

and

\[
\text{var}(X_V) = E \left[ (X_V - E[X_V])^2 \right] = \left[ \frac{1}{4} (1 + m_1) + \frac{1}{4} (1 + m_2) \right] \left( 1 - \frac{m_1 + m_2}{2} \right)^2 + \left[ \frac{1}{4} (1 - m_1) + \frac{1}{4} (1 - m_2) \right] \left( -1 - \frac{m_1 + m_2}{2} \right)^2 = 1 - \left( \frac{m_1 + m_2}{2} \right)^2. \tag{4.12}
\]

The values of \( m_1 \) and \( m_2 \) provide two degrees of freedom. One degree of freedom is to insure that the discounted asset value, using the money account as numeraire, is a martingale under the risk-neutral measure \( Q \). The second is to fit the correlation between the asset value and the term structure.

The first condition is
\[ E \left[ \frac{V(t + h)}{V(t)} \right] = E \left[ \exp \left( \sigma_V X_V(t) \sqrt{h} \right) \right] = \exp (rh), \quad (4.13) \]

where \( X_V(t) \) is a random variable whose mean and variance defined in equations (4.11) and (4.12), respectively.

Another condition that is needed to solve for the values of \( m_1 \) and \( m_2 \) stems from matching the correlation between the random variables \( X_f(t) \) and \( X_V(t) \) to the correlation between asset value and risk-free rate \( \rho \):

\[ Cov[X_f(t), X_V(t)] = \frac{m_1 - m_2}{2} = \rho. \quad (4.14) \]

Solving these two equations leads to:

\[ m_1 = \frac{A+B}{2}, \]
\[ m_2 = \frac{A-B}{2}, \quad (4.15) \]

where

\[ A = \frac{4 \exp(r(t)h) - 2(a+b)}{a-b} \]
\[ B = 2\rho, \]

and where \( a = \exp \left( \sigma_V \sqrt{h} \right) \) and \( b = \exp \left( -\sigma_V \sqrt{h} \right) \).

We recognize that the implied values of \( m_1 \) and \( m_2 \) do not yield a perfect recombining condition. When \( X_f \) is set to have mean zero and variance 1, \( X_V \) would have a variance that is node dependent, as shown in equation (4.12).

Using equation (4.13) this implies that

\[ \text{var} \left( \ln \left( \frac{V(t + h)}{V(t)} \right) \right) = \text{var} \left( \sigma_V X_V(t) \sqrt{h} \right) = \sigma_V^2 h \times \text{var} \left( X_V(t) \right) = \sigma_V^2 h \left( 1 - \left( \frac{m_1 + m_2}{2} \right)^2 \right). \quad (4.16) \]
Given that \( \sigma_v \) is assumed to be constant in the model, for the asset value process tree to be recombining in the limit, the necessary and sufficient condition is that \((\frac{m_1 + m_2}{2})^2\) tends to zero. From equation (4.15), we have

\[
\left(\frac{m_1 + m_2}{2}\right)^2 = \frac{2\exp(f(t|node)h) - \left(\exp(\sigma_s\sqrt{h}) + \exp(-\sigma_s\sqrt{h})\right)}{\exp(\sigma_s\sqrt{h}) - \exp(-\sigma_s\sqrt{h})}.
\]

This shows that, by construction, no bivariate lattice is perfectly recombining in a framework in which stochastic interest rates as well as other sources of risk are modeled simultaneously. However, as the length of one time step \( h \) on the lattice goes to zero, the variance of asset returns tends to converge to \( \sigma_v^2 h \), which is node independent.

\[
\lim_{h \to 0} \left(\frac{m_1 + m_2}{2}\right)^2 = \lim_{h \to 0} \frac{2f(t|node)h - (\sigma_s\sqrt{h} - \sigma_s\sqrt{h})}{\sigma_s\sqrt{h} + \sigma_s\sqrt{h}} = \lim_{h \to 0} \frac{2f(t|node)h}{2\sigma_s\sqrt{h}} = \lim_{h \to 0} f(t|node)\sqrt{h} = 0. \tag{4.17}
\]

We construct the bivariate lattice of 500 time steps. This means that, for a bond of 10-year maturity, the length of time step \( h \) is about 1 week (7.3 days = 365 \times 10/500). For a bond of shorter maturity, the length of a one time step in the valuation bivariate lattice shortens accordingly. The reverse holds for bonds of longer maturities.

### 4.4.4 The Leland & Toft estimation

We rely on the Leland & Toft (1996) model (see appendix in Chapter 3) to estimate initial asset value \( V_0 \), asset return volatility \( \sigma_v \), and default barrier \( V_b \). The fundamental variable in the models is the value of the firm’s assets, which is assumed to evolve as a geometric Brownian motion under the risk-adjusted
The constant risk-free interest rate is denoted \( r \), \( \beta \) is the payout ratio, \( \sigma \) is the volatility of the asset value, and \( W_t \) is a standard Wiener process under the risk-adjusted measure.

Default is triggered by the shareholders' endogenous decision to stop servicing debt. Although the exact asset value at which this occurs is determined by several parameters as well as by the characteristics of the respective models, it is always a constant which we denote by \( V_b \). In Leland & Toft (1996), the firm continuously issues debt of maturity \( T \); therefore, the firm also continuously redeems debt issued many years previously. Hence, at any given time, the firm has many overlapping debt contracts outstanding, each serviced by a continuous coupon. Coupons to individual debt contracts are designed such that the total cash flow to debt holders (the sum of coupons to all debt contracts plus nominal repayment) is constant.

We use Maximum Likelihood estimation together with Leland & Toft (1996) to compute the initial asset value \( V_0 \), default barrier \( V_b \), and the volatility of the asset returns \( \sigma_V \).

The methodology utilized, first proposed by Duan (1994) in the context of deposit insurance, uses price data from one or several derivatives written on the assets to infer the characteristics of the underlying, unobserved, process. In principle, the "derivative" can be any of the firm's securities but, in practice, only equity is likely to offer a precise and undisrupted price series.

The maximum likelihood estimation relies on a time series of stock prices, \( E^\text{obs} = \{ E^\text{obs}_i : i = 1 \ldots n \} \). A general formulation of the likelihood function using a change of variables is documented in Duan (1994). If we let \( w \left( E^\text{obs}_i, t_i; \sigma \right) \equiv E^{-1} \left( E^\text{obs}_i, t_i; \sigma \right) \) be the inverse of the equity function, the likelihood function
for equity can be expressed as

$$L_E (E_{obs}, \sigma) = L_{ln} w \left( \ln w \left( E_{obs}^{i}, t_i; \sigma \right) : i = 2...n; \sigma \right)$$

$$- \sum_{i=2}^{n} \ln \omega_i \frac{\partial E (\omega_i, t_i; \sigma)}{\partial \omega_i} \bigg|_{\omega_i=\omega (E_{obs}^{i}, t_i; \sigma)}.$$

$L_{ln} w$ is the standard likelihood function for a normally distributed variable, the log of the asset value, and $\frac{\partial E}{\partial \omega_i}$ is the "delta" of the equity formula.

The value of $\rho$ is estimated using a window of 250-day implied asset returns and risk-free rates observed prior to the transaction date $t$.

On the bivariate lattice, default occurs when asset value $V$ falls below the barrier $V_b$, which is estimated using the Leland & Toft (1996) model. The value of $V_b$ is determined at the transaction time $t$, and remains the same along the tree. Backward induction is used to solve for the bond price at $t$. On every node, if default does not occur, the value of the bond equals the one-period coupon plus the continuation value of the bond. Should default occur, the bond is recovered with $\psi$ of its face value.

### 4.5 Decomposing put option value

We use the following parameter values to price regular bonds and putable bonds:

- Risk-free rate $r$ (in the LT estimation), swap rate interpolated to match each individual bond maturity

$$\text{Payout rate } \beta = \left( \frac{\text{Interest Expense}}{\text{Total Liabilities}} \right) \times \text{Leverage} + \text{Dividend Yield} \times (1 - \text{Leverage})$$

- Tax rate $\tau = 0.20$, lower than the corporate tax rate to reflect personal tax benefits to equity returns, thus reducing the tax advantage of debt.

- Debt nominal $N$, total liabilities from firm's balance sheet
• Coupon $C = r \times N$

• Bankruptcy cost $\kappa = 15\%$

• Bond recovery rate $\psi = 40\%$

We first examine the statistic properties of market putable and regular bond yield spreads over swap rates (reference risk-free benchmark) with matched maturities. As reported in Table 4.6, the average of observed putable bond spreads over swap rates is approximately 50 basis points. The average of observed regular bond spreads over swap rates is approximately 99 basis points. Our model estimates an average putable bond spread of 44 basis points, while the average of model regular bond spreads is 90 basis points. The model underestimates putable and regular bond spreads by 10 and 6 basis points on average. The discrepancies could be largely attributed to the liquidity premia that are not captured by the model.

[insert Table 4.6]

Table 4.7 displays a statistic summary of the parameters estimated by implementing the LT model, and some independent variables used in our regression analysis. The average asset value is approximately 49.7 billion dollars, which is 2.8 billion lower compared to the firm value reported in Table 1. Asset value can be viewed as unlevered firm value, while firm value reflects tax benefits of debt and potential bankruptcy loss. The average default barrier is 26.4 billion dollars, and equals 98% of the average nominal debt amount. The average asset return volatility is 18%. The correlation between firm assets and risk-free interest rates is $-2.33\%$ with negative and positive extremes of $-37\%$ and 26%, respectively. The payout rate of assets is 2.7% on average, similar to 2.64% in Ericsson et al. (2006).
We rely on our above model to decompose the values of put options. We compute the model putable spreads, then we calculate the model spreads of the comparable non putable bonds. We obtain the model values of the put options by subtracting the model putable spreads from the model spreads of comparable regular bonds that have the same features as the putable bonds with no put options attached.

The average difference between regular and putable bond spreads is 49 basis points. This is our proxy for the value of the market put options; we fully realize that a proportion of this difference is due to the difference in coupons and maturities. Later in this section, we will discuss and correct this aspect. Figure 4.3(I) illustrates the market values of the putable and the nonputable bonds spreads, and their model counterparties.

Using our model, we compute the value of the put option embedded in a putable and an otherwise identical nonputable bond. As illustrated in Figure 4.3(II), the model spreads of comparable regular bonds and putable bonds are 83 and 44 basis points on average. The 39-basis point difference represents the average of the model values of the put options. Given that our model captures interest rate risk and credit risk, these 39 bps comprise insurance against default risk and interest risk.

We turn our attention to investigating the model value of the put option. In essence, we wish to quantify which proportion of the 39 bps is due to credit risk insurance, and which proportion is attributed to interest rate risk. Hence, we compute the spreads of comparable default-free putable bonds -we reestimate putable bonds while shutting down the default dimension of the bivariate lattice. The average comparable default-free putable bond model spread is approximately −14 basis points. To clarify the negative sign that may seem initially strange, the comparable putable default-free bond yield
should be lower than the benchmark swap rate because of the embedded put. This implies that, amongst the 39 basis points, 14 basis points are insurance against interest rate fluctuations, and the remaining 25 basis points comprise insurance against default risk. This is illustrated in Figure 4.3(III).

After decomposing the credit risk and the term structure risk in the model price of the put option, we direct our attention to the core task of decomposing the market implied price of the put option. Figure 4.3(IV) shows the proportions of interest rate risks and credit risks contained in the average put values of 49bps.

There are 10 basis points left unexplained in the market spreads of the put options (99bps − 50bps − 39bps). To understand the remaining 10 basis points, we first figure out the proportion due to the property difference between regular bonds and putable bonds. In order to do so, we compare the spreads between the model regular bonds and the model comparable regular bonds that have the same coupon rate and time to maturity as the regular bonds. The average difference is 7 basis points, which captures the difference in credit risk and interest risk premia due to feature difference. Note that this suggests that the remaining 3 basis points are attributed to other factors including liquidity enhancement provided by the put options. The result is consistent with the difference between the residual (market − model) spreads of regular bonds, 10 basis points, and putable bonds, 6 basis points.

We find that the average value of insurance against risk factors provided by the put options attached to corporate bonds in term of spread is approximately 42 basis points. 60% of the spreads is insurance against default risk. 33% is insurance against interest rate risk. 7% is due to other factors including liquidity enhancement.
4.6 Conclusion

The most important drivers of corporate bond prices are likely to be interest rate risk, default risk, and illiquidity. The option to put back the bond to the issuers provides insurance against all three. In this article, we shed light on which risks are insured against by embedded puts, and to what extent.

Using a sample of putable bond and comparable regular bond transactions, we find that the put option feature does significantly hedge against all three risks. The reduction in corporate bond yield spread due to the presence of a put represents, on average, just over 40% of the yield spread. By means of regression analysis we show that the put option value (as measured by the spread reduction) is related to proxies for default, interest rate, and marketability risk.

To further understand the composition of the put option feature, we develop a bivariate lattice model that simultaneously captures correlated credit and term structure risks. The model is then applied to price regular and putable bonds to decompose the risk components contained in the put options.

We find that the dominant source of spread reduction is attributable to default risk - an average of 60% of the reduction. But, we find that when default is imminent and the firm may not be able to honor the option, the put option value is significantly reduced.

Perhaps surprisingly, only a small fraction (7%) of the spread reduction by put option is due to other nondefault factors including illiquidity. Put options are less valuable for bonds issued by larger firms which enjoy better marketability. The values of put options increase as market liquidity drops. Put options are more likely to be exercised when interest rates are high, which, in turn, increases their values.
### Table of Firms

<table>
<thead>
<tr>
<th>Firm Name</th>
<th>Number of Transactions</th>
<th>Firm Size ($Billion)</th>
<th>Leverage</th>
<th>Payout Rate</th>
<th>Asset &amp; Riskfree Rate Correlation</th>
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<tbody>
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<td>ALBERTSON'S INC</td>
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<td>0.031</td>
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<td>3634</td>
<td>56%</td>
<td>0.017</td>
<td>-0.039</td>
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<td>Firm Size ($billion)</td>
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<td>27408</td>
<td>48%</td>
<td>0.029</td>
<td>-0.030</td>
</tr>
<tr>
<td>WILLAMETTE INDUSTRIES</td>
<td>12</td>
<td>6460</td>
<td>42%</td>
<td>0.032</td>
<td>-0.019</td>
</tr>
<tr>
<td>XEROX CORP</td>
<td>43</td>
<td>42132</td>
<td>61%</td>
<td>0.050</td>
<td>-0.027</td>
</tr>
</tbody>
</table>
TABLE 4.1, DESCRIPTIVE STATISTICS - FIRM & BOND CHARACTERISTICS

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firm size (billion $'s)</td>
<td>1039</td>
<td>52.49</td>
<td>75.27</td>
<td>1.60</td>
<td>469.067</td>
</tr>
<tr>
<td>Equity (billion $'s)</td>
<td>1039</td>
<td>22.58</td>
<td>27.63</td>
<td>0.17</td>
<td>183.40</td>
</tr>
<tr>
<td>Nom. debt (billion $'s)</td>
<td>1039</td>
<td>29.91</td>
<td>65.77</td>
<td>0.88</td>
<td>446.61</td>
</tr>
<tr>
<td>Leverage</td>
<td>1039</td>
<td>52%</td>
<td>20%</td>
<td>6%</td>
<td>96%</td>
</tr>
<tr>
<td>SP rating</td>
<td>1039</td>
<td>8.63</td>
<td>3.92</td>
<td>1.00</td>
<td>27.00</td>
</tr>
</tbody>
</table>

Regular bond

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trans size (million $'s)</td>
<td>1039</td>
<td>2.65</td>
<td>3.79</td>
<td>0.01</td>
<td>31.60</td>
</tr>
<tr>
<td>Offering amount (million $'s)</td>
<td>1039</td>
<td>324.33</td>
<td>203.72</td>
<td>1.50</td>
<td>1000.00</td>
</tr>
<tr>
<td>Age</td>
<td>1039</td>
<td>4.30</td>
<td>3.38</td>
<td>0.00</td>
<td>16.75</td>
</tr>
<tr>
<td>Time to maturity</td>
<td>1039</td>
<td>15.05</td>
<td>14.36</td>
<td>0.52</td>
<td>99.71</td>
</tr>
<tr>
<td>Coupon</td>
<td>1039</td>
<td>7.25</td>
<td>1.11</td>
<td>2.25</td>
<td>11.13</td>
</tr>
</tbody>
</table>

Putable bond

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trans size (million $'s)</td>
<td>1039</td>
<td>0.33</td>
<td>0.51</td>
<td>0.00</td>
<td>4.80</td>
</tr>
<tr>
<td>Offering amount (million $'s)</td>
<td>1039</td>
<td>269.89</td>
<td>132.88</td>
<td>10.00</td>
<td>600.00</td>
</tr>
<tr>
<td>Age</td>
<td>1039</td>
<td>5.00</td>
<td>3.57</td>
<td>0.00</td>
<td>17.73</td>
</tr>
<tr>
<td>Time to maturity</td>
<td>1039</td>
<td>26.26</td>
<td>10.75</td>
<td>2.28</td>
<td>99.55</td>
</tr>
<tr>
<td>Coupon</td>
<td>1039</td>
<td>7.33</td>
<td>0.99</td>
<td>5.55</td>
<td>10.20</td>
</tr>
<tr>
<td>Variable</td>
<td>Obs</td>
<td>Mean</td>
<td>Std. Dev.</td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-----</td>
<td>--------</td>
<td>-----------</td>
<td>-------</td>
<td>--------</td>
</tr>
<tr>
<td><strong>Dependant Variables</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moody's Default Premium</td>
<td>1039</td>
<td>0.86</td>
<td>0.24</td>
<td>0.50</td>
<td>1.48</td>
</tr>
<tr>
<td>VIX</td>
<td>1039</td>
<td>23.01%</td>
<td>6.14%</td>
<td>10.66%</td>
<td>44.92%</td>
</tr>
<tr>
<td>SP500 EWRETĐ*</td>
<td>1039</td>
<td>0.11%</td>
<td>1.18%</td>
<td>-3.66%</td>
<td>5.88%</td>
</tr>
<tr>
<td>Pastor &amp; Stambaugh Level</td>
<td>1039</td>
<td>-0.033</td>
<td>0.068</td>
<td>-0.250</td>
<td>0.162</td>
</tr>
<tr>
<td>Swap Rate 5 years</td>
<td>1039</td>
<td>4.93%</td>
<td>1.27%</td>
<td>2.12%</td>
<td>7.82%</td>
</tr>
</tbody>
</table>
Table 4.3A, Regression Analysis on Market Putable Bond Spreads

Our regression method fits cross-sectional time-series regression models. It can fit fixed-effects (within), between-effects, and random-effects (mixed) models as well as population-averaged models. Dependent variables are given in column headings, explanatory variables in first column; Percentages in column 4 are p-values. Regressions are run as random effects GLS with an AR(1) error structure, and use a method developed by Baltagi & Wu (1999) to adjust for the unbalanced nature of the data panel. Same method is applied to regression analysis reported in Table 4B, 5 and 6.

| Coef. | Std. Err. | z   | P>|z| | 95% Conf. Interval |
|-------|-----------|-----|-----|---------------------|
| leverage | 234.5074 | 16.1833 | 14.49 | 0.0000 | 202.789 - 266.226 |
| equity sigma | 140.7576 | 23.6786 | 5.94 | 0.0000 | 94.348 - 187.167 |
| S&P rating | 0.5331 | 1.0863 | 0.49 | 0.6240 | -1.596 - 2.662 |
| Moody's def. prem. | 2.7253 | 8.4681 | 0.32 | 0.7480 | -13.872 - 19.322 |
| VIX | 0.7677 | 0.2633 | 2.92 | 0.0040 | 0.252 - 1.284 |
| S&P return | 194.3806 | 112.7540 | 1.72 | 0.0850 | -26.613 - 415.374 |
| bond maturity | 0.0000 | 0.0006 | -0.07 | 0.9430 | -0.001 - 0.001 |
| bond age | 0.0004 | 0.0026 | 0.13 | 0.8930 | -0.005 - 0.006 |
| firm size | -0.0001 | 0.0001 | 1.02 | 0.3060 | 0.000 - 0.000 |
| P-S index | -42.8082 | 21.0816 | -2.03 | 0.0420 | -84.127 - 1.489 |
| coupon | 35.2034 | 3.7038 | 9.5 | 0.0000 | 27.944 - 42.463 |
| CMT 5 year | -28.6989 | 2.0799 | -13.8 | 0.0000 | -32.775 - 24.622 |
| con | -241.0708 | 29.1715 | -8.26 | 0.0000 | -298.246 - 183.896 |

Adjusted $R^2 = 0.5533$
<table>
<thead>
<tr>
<th>Variable</th>
<th>Coef.</th>
<th>Std. Err.</th>
<th>z</th>
<th>P&gt;z</th>
<th>95% Conf. Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>leverage</td>
<td>646.5838</td>
<td>39.0379</td>
<td>16.56</td>
<td>0.000</td>
<td>570.071 - 723.097</td>
</tr>
<tr>
<td>equity sigma</td>
<td>285.3367</td>
<td>59.1994</td>
<td>4.82</td>
<td>0.000</td>
<td>169.308 - 401.365</td>
</tr>
<tr>
<td>S&amp;P rating</td>
<td>1.5620</td>
<td>2.1283</td>
<td>0.73</td>
<td>0.463</td>
<td>-2.609 - 5.734</td>
</tr>
<tr>
<td>Moody's def. prem.</td>
<td>50.9624</td>
<td>22.6497</td>
<td>2.25</td>
<td>0.024</td>
<td>6.570 - 95.355</td>
</tr>
<tr>
<td>VIX</td>
<td>0.0176</td>
<td>0.6957</td>
<td>0.03</td>
<td>0.980</td>
<td>1.346 - 1.381</td>
</tr>
<tr>
<td>S&amp;P return</td>
<td>245.9434</td>
<td>302.5429</td>
<td>0.81</td>
<td>0.416</td>
<td>-347.030 - 838.917</td>
</tr>
<tr>
<td>bond maturity</td>
<td>0.0028</td>
<td>0.0008</td>
<td>3.34</td>
<td>0.001</td>
<td>0.001 - 0.004</td>
</tr>
<tr>
<td>bond age</td>
<td>0.0126</td>
<td>0.0044</td>
<td>2.9</td>
<td>0.004</td>
<td>0.004 - 0.021</td>
</tr>
<tr>
<td>firm size</td>
<td>-0.0003</td>
<td>0.0001</td>
<td>-2.89</td>
<td>0.001</td>
<td>-0.0001 - 0.0000</td>
</tr>
<tr>
<td>P-S index</td>
<td>-188.7807</td>
<td>56.5153</td>
<td>-3.34</td>
<td>0.001</td>
<td>-299.549 - 78.013</td>
</tr>
<tr>
<td>coupon</td>
<td>-1.0154</td>
<td>4.8268</td>
<td>-0.21</td>
<td>0.833</td>
<td>-10.476 - 8.445</td>
</tr>
<tr>
<td>t5y</td>
<td>-7.5403</td>
<td>4.6811</td>
<td>-1.61</td>
<td>0.107</td>
<td>-16.715 - 1.635</td>
</tr>
<tr>
<td>con</td>
<td>-321.1071</td>
<td>57.9343</td>
<td>-5.54</td>
<td>0.000</td>
<td>-434.656 - 207.558</td>
</tr>
</tbody>
</table>

Adjusted $R^2 = 0.2149$
### Table 4.4, Regression Analysis on Put Options (Market)

| Variable            | Coef.  | Std. Err. | z      | P>|z|  | [95% Conf. Interval] |
|---------------------|--------|-----------|--------|-----|----------------------|
| leverage            | 429.1973 | 34.3088      | 12.51  | 0.000 | 361.9534 - 496.4413   |
| equity sigma        | 135.7978 | 51.6791      | 2.63   | 0.009 | 34.5085 - 237.0870    |
| Moody's def. prem.  | 42.5883  | 19.8582      | 2.14   | 0.032 | 3.6670 - 81.5097      |
| VIX                 | -0.6711  | 0.6100       | -1.1   | 0.271 | -1.8666 - 0.5245      |
| S&P return          | 131.5280 | 265.7805     | 0.49   | 0.621 | -389.3923 - 652.4482  |
| firm size           | -0.0004  | 0.0001       | -3.98  | 0.000 | -0.0006 - -0.0002     |
| P-S index           | -131.4099 | 49.5915      | -2.65  | 0.008 | -228.6074 - -34.2124  |
| CMT 5 year          | 16.6322  | 3.8086       | 4.37   | 0.000 | 9.1675 - 24.0969      |
| con                 | -283.5314 | 40.0547      | -7.08  | 0.000 | -362.0372 - -205.0256 |

Adjusted $R^2 = 0.2340$
TABLE 4.5, IMPACT OF PUT OPTION FEATURES ON THE VALUE OF THE OPTION

| Feature                        | Coef.   | Std. Err. | z     | P>|z| | [95% Conf. Interval] |
|-------------------------------|---------|-----------|-------|------|---------------------|
| dates to last put             | 0.029137| 0.004935  | 5.9   | 0    | 0.0194638 - 0.03881 |
| dates to first put            | -0.03145| 0.008033  | -3.91 | 0    | -0.0471929 - 0.0157 |
| number of put/maturity        | 107001.7| 66847.04  | 1.6   | 0.109| -24016.11 - 238019.5|
| dates to first put/maturity   | -50.4856| 55.10592  | -0.92 | 0.36 | -158.4912 - 57.52003|
| in the money                  | 103.0036| 9.635411  | 10.69 | 0    | 84.11859 - 121.8887 |
| S&P rating                    | 3.95331 | 0.97625   | 4.05  | 0    | 2.039896 - 5.866724 |
| Moody’s def. prem.            | 47.82498| 17.57578  | 2.72  | 0.007| 13.37708 - 82.27287 |
| VIX                           | -0.33385| 0.704944  | -0.47 | 0.636| -1.715518 - 1.04781 |
| firm size                     | -0.00019| 6.23E-05  | -3.1  | 0.002| -0.0003151 -7.1E-05 |
| P-S index                     | -116.393| 57.73799  | -2.02 | 0.044| -229.557 - 3.22829 |
| Cons                          | -49.8721| 24.60998  | -2.03 | 0.043| -98.10673 - 1.63737 |

Adjusted $R^2 = 0.3022$
Table 4.6, Bond Spread Summary

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Putable Mkt Spread (bps)</td>
<td>1039</td>
<td>49.9</td>
<td>78.0</td>
<td>-161.9</td>
<td>476.6</td>
</tr>
<tr>
<td>Putable Mod Spread (bps)</td>
<td>1039</td>
<td>44.0</td>
<td>97.9</td>
<td>-151.9</td>
<td>719.3</td>
</tr>
<tr>
<td>Regular Mkt Spread (bps)</td>
<td>1039</td>
<td>99.1</td>
<td>153.4</td>
<td>-120.1</td>
<td>2318.2</td>
</tr>
<tr>
<td>Regular Mod Spread (bps)</td>
<td>1039</td>
<td>89.8</td>
<td>135.5</td>
<td>0.0</td>
<td>1044.6</td>
</tr>
<tr>
<td>Hypothetical Regular Spread (bps)</td>
<td>1039</td>
<td>83.5</td>
<td>106.7</td>
<td>0.0</td>
<td>719.3</td>
</tr>
</tbody>
</table>

Table 4.7, Leland & Toft (1996) Estimates

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leland &amp; Toft Estimates</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asset Values (billion $'s)</td>
<td>1039</td>
<td>49.737</td>
<td>71.742</td>
<td>1.537</td>
<td>466.585</td>
</tr>
<tr>
<td>Barrier (billion $'s)</td>
<td>1039</td>
<td>26.412</td>
<td>61.108</td>
<td>0.660</td>
<td>421.247</td>
</tr>
<tr>
<td>SigmaV</td>
<td>1039</td>
<td>17.78%</td>
<td>10.45%</td>
<td>1.00%</td>
<td>79.24%</td>
</tr>
<tr>
<td>Correlation between V and r</td>
<td>1039</td>
<td>-2.33%</td>
<td>7.04%</td>
<td>-37.25%</td>
<td>25.66%</td>
</tr>
<tr>
<td>Payout Ratio</td>
<td>1039</td>
<td>2.72%</td>
<td>1.25%</td>
<td>0.00%</td>
<td>17.03%</td>
</tr>
</tbody>
</table>
Figure 4.1, Market Put Option Values by Credit Rating and Liquidity Index

(A) 

(B)
Figure 4.2, A Bivariate Lattice
FIGURE 4.3, DECOMPOSITION OF PUT OPTION VALUES

I

Non-puttable bond

Puttable bond

II

Mid value of put option

49 bps

Puttable bond

Non-puttable bond

III

From hypothetical Default-free put Bond spread

IV

Hypothetical Mod Non-put Spread

83 bps

Non-puttable bond

Puttable bond

V

Hypothetical Mod Non-put Spread

83 bps

Non-puttable bond

Puttable bond

VI
Chapter 5

Conclusion and Summary

Contingent claims models have been used as a powerful tool to study leverage ratio and to price corporate bond and credit derivatives. A significant advantage of those models is that they provide not only economic intuition but also quantitative implications to bridge theories and applications. This thesis contributes to the literature from both theoretical and empirical perspectives. At first glance, the topics covered may seem quite distinct from each other – managerial entrenchment and firm policies v.s. credit risk. They are in fact highly correlated and influence each other. Contingent claims models offer a useful framework to study correlated corporate policies and security valuation in a forward-looking dynamic setting.

Managerial agency issues are of great importance in shaping firm dividend policies and selected leverages. However, they have not received much of attention in the contingent claims literature so far. In this thesis, I develop a dynamic valuation model that characterizes dividend payout policies and capital structure through the agency issues between entrenched managers and shareholders who have limited power to fire the managers. Specifically, the entrenched managers make leverage choices and undertake dividend payout decisions to optimize their own utility and to prevent the shareholders from
exercising their threat to fire simultaneously.

I demonstrate that leverage choices are subject to managerial entrenchment and to the relative bargaining power of creditors. The results suggest that balanced bargaining strength between a firm and its creditors could be optimal in order to maximize firm efficiency in the presence of agency problems. Challenging the conventional thought that managers are always closer to shareholders than to debtholders, I show that managers' preference on risk choice/cash payout level tallies with that of debtholders when a firm is distant from financial distress. Shareholder-manager conflicts over risk choice and payout rate disappear and the interests of managers and shareholders become naturally aligned as a firm approaches bankruptcy. The evidence serves as a reminder to exercise caution when making assumptions on shareholder-manager conflicts because they change dynamically with a firm's financial health.

The results suggest dividend yields decrease with leverage ratios and managerial entrenchment. With sufficient entrenchment, managers are able to stop dividend payments altogether without triggering shareholders' firing actions. The evidence that leverage ratios matter more for firms with lower entrenchment suggests that empirical studies should control for entrenchment in the cross-section.

There are several interesting avenues by which to extend the model: endogenizing managerial entrenchment to managerial competency or to shareholders' monitoring, contractual provisions such as golden parachutes, and adding information asymmetries and growth opportunities. In addition, the model can be calibrated to observed firm information to measure implicit managerial control power.

During the last decade, credit derivative markets experienced exponential growth. The availability of the credit derivative data allows us to evaluate firm credit worthiness from a new perspective. Using a set of structural models, we
have evaluated the price of default protection for a sample of US corporations. We find that one of our studied models has little difficulty in predicting default swap premia on average. This result departs from what has been found in corporate bond markets. For robustness, we perform the same exercise for bond spreads by the same issuers on the same trading date. As previous work has found, bond spreads relative to the Treasury curve are systematically underestimated. However, this is not the case when the swap curve is used as a benchmark, suggesting that previously documented underestimation results may be sensitive to the choice of risk free rate. A reason why the swap curve may be a more appropriate benchmark for corporate bond spread measurement is that it lies closer to the cost of funding for traders in the bond market. The bond spread over the swap curve thus measures the additional yield these market participants require to participate in this market when faced with the alternative of dealing in credit derivatives.

To the best of our knowledge, the third essay constitutes the first paper that closely examines putable corporate bonds and decomposes their embedded option values. It is of great interest to study this topic for portfolio hedging and risk management purposes. The most important drivers of corporate bond prices are likely to be interest rate risk, default risk, and illiquidity. The option to put back the bond to the issuers provides insurance against all three. In this article, we shed light on which risks are insured against by embedded puts, and to what extent.

Using a sample of putable bond and comparable regular bond transactions, we find that the put option feature does significantly hedge against all three risks. The reduction in corporate bond yield spread due to the presence of a put represents, on average, just over 40% of the yield spread. By means of regression analysis we show that the put option value (as measured by the spread reduction) is related to proxies for default, interest rate, and
marketability risk.

To further understand the composition of the put option feature, we develop a bivariate lattice model that simultaneously captures correlated credit and term structure risks. The model is then applied to price regular and putable bonds to decompose the risk components contained in the put options.

We find that the dominant source of spread reduction is attributable to default risk - an average of 60% of the reduction. But, we find that when default is imminent and the firm may not be able to honor the option, the put option value is significantly reduced.

Perhaps surprisingly, only a small fraction (7%) of the spread reduction by put option is due to other nondefault factors including illiquidity. Put options are less valuable for bonds issued by larger firms which enjoy better marketability. The values of put options increase as market liquidity drops. Put options are more likely to be exercised when interest rates are high, which, in turn, increases their values.

The merits of the bivariate lattice model and our implementation methodology deserve a special note. The model is flexible enough to be applied to valuate contingent claims securities that are subject to more than one risk sources, such as convertible and callable bonds. The maximum likelihood estimation allows not only for estimating parameters of unobservable underlying asset from observed contingent claims - equity values, but also for computing the correlation between the time series of risk sources in a time window of selected length.
Bibliography


