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Reporting bias in incomplete information model

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HIGHLIGHTS

- Model credit risk in an opaque environment under perceived reporting bias.
- Bias is modelled with a skew normal distribution.
- In the presence of upward bias, the probability of default increases non-linearly with the amount of reporting noise.
- In the presence of upward bias there is a positive uncertainty premium over the credit term structure.

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ABSTRACT

Company financial reports are likely to be systematically biased. In this paper, we extend the Duffie and Lando (2001) model with a skewness correction which can account for both random and directional components of reporting noise.

1. Introduction

Firms reveal information about their financial health through the publication of financial reports. The accuracy of these reports is critical for investors as they provide the closest estimate of the unobserved underlying variables. However, the usefulness of published information is limited by noise caused by their periodicity, statistical errors and reporting bias (Fischer and Verrecchia, 2000). Noisy financial reports are particularly problematic for structural credit risk models that assume perfectly observable parameters.

Duffie and Lando (2001) (D–L) offer an extension of a structural credit risk model that allows for uncertainty in the asset value of a firm due to noisy but unbiased accounting reports. We argue that financial information may be systematically biased and propose an extension of the D–L model to assist creditors in the evaluation of credit risk in an opaque environment under perceived bias.

For firms, the direction of bias in accounting reports is ambiguous and ultimately a testable empirical question. On the one hand, regulation stipulates conservative accounting practices which will manifest as the understatement of the book value of assets (Zhang, 2000, Beaver and Ryan, 2005). For example, Basu (1997) illustrates that under accounting conservatism, an increase in the expected life of a fixed asset would not be recognised currently, while its decrease would result in asset impairment, reducing the recorded value of that asset. On the other hand, flexibility within accounting rules and the ability to exercise judgement in the preparation of accounting reports create an opportunity to overstate asset values and present the entity's financial position favourably. Mulford and Comiskey (2002) document several cases where creative accounting is used to inflate reported assets such as receivables, inventory and investments. Lev (2003) presents anecdotal evidence showing that in the late 1990s, over 90% of financial report restatements revised earnings downward. This sharp increase in downward revisions coincided with a major move by the Securities and Exchange Commission (SEC) to curb earnings manipulation. Discretionary disclosure can also create an upward bias in the firm value as firms, given an opportunity, will withhold sensitive

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information from the public that can have adverse implications for the firm value (Shin, 2003; Verrecchia, 1983).

2. Biased incomplete information model

In the D–L model, investors observe a periodic noisy signal of the asset value from accounting reports, from which investors try to deduce the actual asset value. The noise stems from obsolescence and errors made during the preparation of these reports. Intuitively, when investors only observe imperfect accounting information, the actual asset value may lie closer to the default boundary, and if close enough, default may occur instantaneously. This generates an unpredictable default time similar to a reduced form model, which ensures a non-zero short-term credit spread consistent with observed data. Expressed mathematically,

$$Y_t = X_t + U_t \tag{1}$$

where Y_t is the log of the observed asset value, $X_t = \log(V_t)$ is the log of the actual asset value V_t, and U_t is the reporting noise, all at time t.

We extend the D–L model to include a directional component in the noise term, reflecting systematic reporting bias.[1] To capture both directional and non-directional components in a single noise term, we suppose that U_t follows a skew normal distribution first proposed by Azzalini (1985). In the most generic form, a skew normal distribution is the product of a normal density function with a cumulative normal distribution function that regulates the skewness. In our model, the density of U_t is given by

$$f(u; a, \omega) = \exp\left(-u^2/2a^2\right)\left(1 + \mathrm{erf}(\omega u/\sqrt{2})\right)/(\sqrt{2\pi}\, a) \tag{2}$$

where a and ω are the parameters regulating the shape of the density. ω can also be expressed as $\frac{\delta}{\sqrt{1-\delta^2}}$, so that skewness is bounded by -1 and 1. Note that in the absence of bias ($\delta = 0$), a regulates the amount of noise that is dispersed symmetrically around the observed asset value. When noise becomes biased ($\delta \neq 0$), both a and δ determine the amount of noise and its degree of asymmetry.

Having specified the noise distribution, we revise the D–L conditional asset density function.[2] Conditional on the last-known true asset value, the asset diffusion process, the current reported asset value and a perceived distribution of accounting noise, investors derive a posterior probability density function for the current actual log asset value via Bayes' rule:

$$b(x|Y_t, z_0, t) = f(Y_t - x)\ \psi\ \phi_Z(x)/\phi_Y(Y_t) \tag{3}$$

where x is the actual log asset value, Y_t is the reported log asset value, z_0 is the last-known actual log asset value ($\log(Z_0)$), $\underline{v}$ is the default boundary ($\log(\underline{V})$), σ is the asset diffusion, $\phi()$ is the normal probability density function, and t is the time since z_0 is observed.

To ensure that the asset value is bounded below by the default barrier, the density $\phi_Z(x)$ is adjusted by $\psi = 1 - \exp\left(-2(z_0 - \underline{v})(x - \underline{v})/\sigma^2 t\right)$.[3] Expanding Eq. (3) and expressing the density function in terms of V_t, we have

$$b_V(V|Y_t, z_0, t) = \sqrt{a^2\beta_0 + \sigma^2 t/2\pi a^2\sigma^2 t} \times \exp[-\beta_1][1 - \exp(\beta_2)][\mathrm{erfc}(\beta_3)]V^{-1} \tag{4}$$

where

$m = \mu - 0.5\sigma^2$
$\tilde{y} = Y - \underline{v}$
$\tilde{x} = x - \underline{v}$
$\tilde{z}_0 = z_0 - \underline{v}$
$\beta_0 = 1 - 2\omega^2/\pi(1 + \omega^2)$
$\beta_1 = (\tilde{y} - \tilde{x})^2/2a^2 + (\tilde{z}_0 + mt - \tilde{x})^2/2\sigma^2 t$
$\beta_2 = -2\tilde{z}_0\tilde{x}/\sigma^2 t$
$\beta_3 = -\omega(\tilde{y} - \tilde{x})/\sqrt{2}$
erfc( ) denotes the complimentary error function.

The distribution of V_t conditional on surviving up to time t is

$$g(V|Y_t, z_0, t) = b_V(V|Y_t, z_0, t) \Bigg/ \int_{\underline{V}}^{\infty} b_V(V|Y_t, z_0, t)\, dV. \tag{5}$$

It follows that the risk-neutral survival probability to time T is given by[4]

$$p(T) = \int_{\underline{V}}^{\infty} (1 - \pi(T, V))\, g(V|Y_t, z_0, t)\, dV \tag{6}$$

$$\pi(T, V) = \Phi\left(\frac{\ln(\underline{V}/V) - mT}{\sigma\sqrt{T}}\right) + \exp\left(\frac{2m\ln(\underline{V}/V)}{\sigma^2}\right)\Phi\left(\frac{\ln(\underline{V}/V) + mT}{\sigma\sqrt{T}}\right) \tag{7}$$

with $\pi()$ being the probability of first passage of a Brownian motion and $\Phi()$ denotes the standard normal cumulative distribution function.

3. Comparable statistics and discussions

This section simulates the impact of reporting bias on a firm's credit risk using our biased incomplete information model. For comparison, we use the same base case parameter values as D–L unless explicitly stated otherwise. That is, a leverage of 90% ($\underline{V}/Y = 78/86.3$), a last-known asset value (Z_0) of 86.3, a risk-free rate (r) of 6%, an asset drift (μ) of 1%, an asset diffusion (σ) of 5%, and a recovery rate (R) of 40%.

First, we investigate the effect of δ on the density function $g(V|Y_t, z_0, t)$ with $a = 0.05$. As shown in Panel A of Fig. 1, with zero bias, the noise is symmetrically dispersed around the observed value. As we introduce upward bias by raising δ, the upper tail of the density function approaches the observed level, reducing the probability that the true asset value lies above the observed level. This is consistent with our hypothesised effect of bias stemming from creative accounting and discretionary disclosures. Conversely, downward bias consistent with conservative accounting is modelled through a negative δ. Panel B of Fig. 1 shows the effect of varying a while maintaining upward or downward bias. The figure clearly shows that since the upper (lower) tail is pinned down due to the upwardly (downwardly) biased report, increasing the amount of noise via a increases the dispersion asymmetrically.

Modelling reporting bias in U_t using skew rather than a normal distribution with a non-zero mean offers two advantages. First, Fig. 1 shows that the mass of the conditional asset density function in the biased incomplete information model is always anchored to the observed level, as the reported value provides the best

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[1] There are different avenues by which bias is introduced into investors' perception. One way, which is the focus of this paper, is through noisy and biased accounting reports. Alternatively, the lagged asset value, z_0, influences investors' perceptions regardless of noise. We thank an anonymous referee for pointing this out.

[2] See Eq. (17) in D–L.

[3] Since investors know the firm has not defaulted yet. Geometrically, the adjustment forces the function $b(x|Y_t, z_0, t)$ to cross zero at $\underline{v}$. More precisely, this expression is a probability such that for a Brownian motion 'pinned' from $Z_0 = z$ to $Z_t = x$ ($z > 0, x > 0$), the process stays above zero. See Eq. (15) in Ibid.

[4] Per Eq. (26) in Ibid.