Estimating Contingent Convertible credit spreads in the Norwegian Bond Market using an option pricing approach

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Abstract

In this paper we model credit spreads on contingent convertible bonds (CoCos) in the Norwegian financial bond market, using a Merton style option model approach. We examine whether the Merton risk default model provides a good measure of CoCo-bond prices. We find that this model, although favoured by its simplicity, is overly sensitive to changes in the volatility of firm asset values, and fails to account for liquidity premiums. We further ask if CoCo prices account for the prepayment risk that are unique to these hybrid equity-like capital instruments. Analogously we ask if CoCo-bonds offer cheap funding for banks relative to equity capital. We find no evidence that bond markets underprices the CoCo-risk of the trial banks. Still we find that CoCos offer cheap funding for banks relative to issuing equity capital. In addition, CoCos offer capital cushion for banks when most needed.

Key words: CoCo-bonds, credit spreads, Merton credit default risk model, Norwegian bank funding costs.

1. Introduction

In this paper we employ a structural credit default model to calculate credit spreads on contingent convertible bonds (CoCo-bonds). The CoCos we study were issued by two banks; the second largest Norwegian savings and loans bank, SpareBank 1 SMN and the largest Norwegian commercial bank, DNB (Den norske Bank) . As we explain below, these instruments were created in the wake of the global financial crises (2008-2009), when banks needed to strengthen their capital base due to stricter regulations. We examine whether the classic Merton risk default model provides a good measure for CoCo-bond prices. We find that the Merton model, although favoured by its simplicity, is overly sensitive to changes in the volatility of company asset values, its only risk parameter. This model also generally fails to account for liquidity premiums. We further ask if CoCo-bond prices account for the inherent risks that are unique to these hybrid, equity-like capital instruments: Do Coco spreads take into account the fact that these securities are perpetual and might not be called? It has become market practice that Cocos, although legally perpetual, are called after 5 years. Further, if CoCos are incorrectly valued, could it be due to the fact that these instruments, on account of their equity-like features, are excluded from many professional fixed income investors' investment universe? We know that typical investors in CoCo-bonds are private savers, i.e., households with net financial wealth and family offices. We suspect that these securities are not as closely monitored as their equity "substitutes". This is why we ask if CoCo-bonds are offering cheap funding for banks relative to equity capital. Below we shortly explain the origin of these hybrid instruments.

The global financial crisis, initially referred to as the sub-prime (mortgages) crises due to the fact that it started with declining housing prices in the US in 2007, gave rise to a host of regulatory measures from financial authorities around the world. Many of the US mortgages, which had been created during the 2000 economic expansion, were of poor (sub-prime) quality and as housing prices continued to decline the book value of the mortgages increasingly exceeded the market value of the collateral, i.e. the houses. This incentivized many US homeowners to default on their loans and normally this would have left the *issuing banks* with portfolios of claims on houses in a deteriorating, illiquid housing market. This would have been bad enough, but as we now know things were far from normal and the situation was a lot worse. Many of the banks that had originated the mortgages had packed and bundled them into new structured securities and sold them on to other banks, who had repacked them and sold them to even different banks and so on. The result was of course that no one knew exactly which banks owned the toxic securities and even if some of these loans could be located, it was almost impossible to calculate their "true" value. Unable to assess the value of the banks' securities the banks were reluctant to lend to each other and as interbank markets in the US and EU quickly froze down, a global financial crisis developed. Next, stock prices collapsed and the global financial crises quickly turned into a global *economic* crises, which called for heavy expansionary monetary and fiscal policy measures, eventually creating a sovereign debt crises.

In the midst of these catastrophic events, authorities across the globe not only launched accommodative policy measures to alleviate the financial crises and combat the recession, they also introduced a variety of new regulatory measures to strengthen banks' and insurance companies' balance sheets and constrain their investment and trading activities.

Norwegian legislation regulating the financial industry conform with EU legislation. In the EU, the *Capital Requirements Directive* (CRD) for the financial service industry is a supervisory framework, which reflects the Basel II and Basel III rules on capital measurements and capital standards. The latest version of the CRD, the CRD IV, recast and replace the Capital Requirements Directive, and applies from 1. January 2014. The directive represents the European Commission's implementation of the revisions to the Basel III Accord, and further introduces a number of important changes to the banking regulatory framework, which were not provided for under the Basel proposals.

The new rules set stronger prudential requirements for banks, requiring them to keep more capital reserves and liquidity capital. Capital of course is expensive and banks must find clever ways to finance these stricter capital requirements. Also, regulators saw the need for instruments which would facilitate the write down of the debt of distressed institutions. These are the main reasons why CoCo-bonds were created. Consequently, contingent convertible bonds offer a viable and potentially cheaper (tax deductible) alternative to equity issue. Although some institutional investors are not permitted to hold these bonds on their balance sheets, CoCo-bonds are still an attractive investment option for other categories of investors offering higher interest rates than senior and subordinated debt.

The rest of this paper is organized as follows: In section 2 we discuss modelling issues in capturing observed credit spreads. Section 3 describes attributes of CoCo-bonds and the historical context that created the need for these hybrid instruments. In section 4 we develop and explain the Merton option based structural credit default model and in section 5 we explain how we have implemented this model. In section 6 we display, discuss and interpret our findings. Section 7 concludes.

2. Modeling credit spreads on bank bonds

The notion of the credit spread puzzle is a well-known conception among credit analysts and researchers alike. It arises out of the seemingly inability of *structured credit default models* to replicate the observed market spread of credit securities. Such models are now textbook items and have been carefully explained in the financial literature e.g., by Merton (1974), Black-Cox (1976), Vasicek-Kealhofer (1993) and Crouhy et. al. (2001). Many explanations have been offered for the credit spread puzzle, i.e., the difference between the observed market spread and the calculated model spread. In attempting to explain the credit spread puzzle researchers and analysts suggest answers to questions like:

(i) Are structural models unable to take account of *some fundamental factors* that matter to investors in credit bonds?
(ii) Is the applied model poorly calibrated?
(iii) Is the data insufficient?

All these types of factors might of course conspire to produce the credit spread puzzle. For instance, with reference to (i) above, we would notice that structural models do not take account of *liquidity* issues, in other words they do not capture any liquidity premium required by investors. In the Norwegian market, this is a major issue because liquidity is low for some instruments and perceived low for even more. Also, referring to (iii) above, time series data on Norwegian credit bonds often only dates back 10-20 years which, in the context of the credit spread puzzle, is too short a time span. Some relevant papers addressing these issues are: Sæbø (2011) and Sæbø (2015).

In their paper, "the Myth of the Credit Spread Puzzle", Feldhütter and Schaefer (2016) argues that the credit spread puzzle all but disappears when they apply a Merton-style model to time series data dating 92 years back in time, spanning the period from 1920 to 2012. They discover that the model matches observed corporate bond spreads well, and further claim that their results hold for a wide range of structural models. Unfortunately, data on Norwegian CoCo-bonds (or credit bonds in general) are not available for a very long period of time. In this study, we use a sample of 162 weekly observations spanning the period from June 3 2014 until October 26 2017. Most likely, we shall encounter a credit spread puzzle, or maybe it is not such a puzzle. More on this later.

Arora et. al. (2005) empirically compare two structural models; the Merton model and the Vaciek-Kealhofer model, and they also consider the reduced-form Hull-White model (1995), (2000) of credit risk. They examine whether the structural models can distinguish defaulters from non-defaulters in equity markets and if the reduced form HW model can do the same job from information gathered in bond markets. They discover that both the VK and the Hull models outperform the basic Merton model. We will elaborate on our decision to use a Merton model to examine CoCo-bond spreads in section 5.

Marin and Ponce (2005) estimate default probabilities for the IBEX-35 companies of the Spanish stock market as of December 31. 2003, using a Merton-style structural model. Because of the low number of listed stocks they are unable to use the Vasicek-Kealhofer model, which relies on historical default data. They conclude that the model offer important insight into the credit risk of each company, although since the credit rating of the IBEX-35 companies is very high, their probability of default is almost zero.

3. Contingent convertible bonds

During the financial crises, and also in response to the resulting sovereign debt crises, debt holders of major insolvent financial companies were often bailed out by the authorities using tax payers money, i.e., the institutions were saved from bankruptcies. Such practices not only has a moral hazard dimension attached to it in terms of encouraging banks to take on excessive risk, it is also considered unfair to the average taxpayer whose money ultimately serves as a guarantee for the wealth of the claim holders and management of the institution that is being bailed out. As mentioned above, a major priority of financial regulators following the global financial crises was to create financial instruments, which could facilitate the write down of the debt of distressed financial institutions, a procedure termed “bail-in” in order to relate and distinguish it from bail out situations. A creation that came out of this process was contingent convertible bonds - CoCo-bonds.

CoCo-bonds are hybrid convertible securities that absorb losses in accordance with their *contractual terms*, when the equity capital of the issuing company (bank) falls below a predetermined threshold. This may happen way before the issuing bank as such becomes insolvent, thus providing banks with higher capital cushions when most needed. (Avdjiev et al. 2015). It could also happen at the point of insolvency. Non-CoCo-bonds such as senior and subordinated bonds may also absorb losses, but this would require the application of a statutory resolution regime, at the point of non-viability. In terms of CoCos however, a credit event would *automatically* trigger a write down of the banks debt (PWD CoCos), or conversion of the CoCos into equity capital (CE CoCos), and as a consequence the equity share of the bank would increase diluting existing shareholders. The activation of the loss absorbing mechanism is thus a function of the capitalization levels of the issuing bank. (Avdjiev et al. 2013).

Legally, senior bonds are also loss absorbing, but prior to the global financial crises investors considered senior bonds as non-defaultable debt, simply because in most markets these instruments had never incurred losses. A new class of loss absorbing senior bonds has now been developed, which go by the name of Tier 3 bonds or Senior Non Preferred Bonds. These securities may be issued by Norwegian banks only after the relevant legislative proposition has been implemented, probably in the course of 2018.

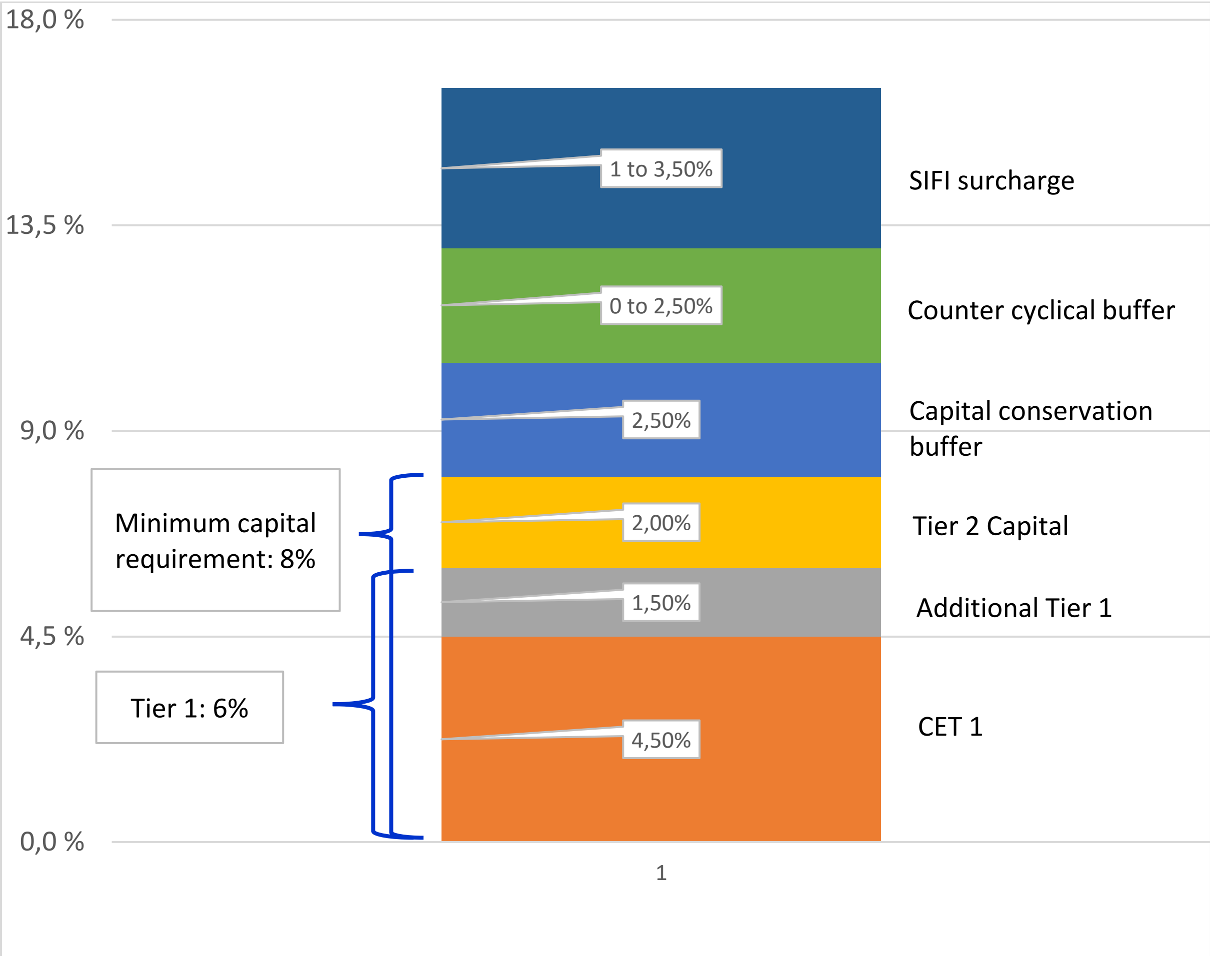
Bank issuance of CoCo-bonds is primarily driven by these instruments’ ability to satisfy regulatory demand for capital adequacy, and as we noted above CoCos might offer cheap funding relative to equity capital. CoCos also provide additional support to senior unsecured debt holders, adding an additional layer of capital, thereby supporting lower funding costs on the senior bonds.

In Europe UK and Swiss banks were the first to issue CoCo-bonds. Now this is a more common instrument issued all over Europe. Still in the current low yield environment, we do expect both CoCo issuance and demand to pick up, as soon as the tax-deductability of these instruments is approved in most countries.

The bulk of demand for CoCo-bonds comes from small investors while institutional investors have been reluctant to invest in these instruments. The main reason for the apparent lack of interest in CoCos from institutional investors like insurance companies is that the CoCos are rated many notches below the issuer rating, and therefore often end up in the high yield category. Also the solvency II framework regulating capital adequacy requirements for insurance companies views CoCos differently than the Basel III regulatory framework regulating the banks. As long as CoCos are treated differently by legislation regulating investors and issuers, this is going to be a burden on demand. In Norway most of the issued CoCos are not rated at all. Also, CoCos, like other hybrids and subordinated securities, are high beta and their performance is more volatile during risk off periods.

Depending on their trigger levels, CoCos count as additional Tier 1 (AT1) and Tier 2 (T2) regulatory capital as defined by the Basel III accord. Consequently, these instruments can enhance banks' regulatory capital buffers and leverage ratios and support issuer ratings. Figure 3.1 illustrates the structure of the minimum regulatory capital required by the Basel III accord.

Figure 3.1 Capital requirements



Core Equity tier 1 (CET 1)	Common shares Retained earnings	CET1 ≥ 4.5% of RWA
Additional Tier 1 (AT 1)	Preferred Shares **High-trigger CoCos**	CET1 + AT1 ≥ 6% of RWA
Tier 2 (T2)	Non-CoCo subordinated debt	CET1 + AT1 + T2 ≥ 8% of RWA

Source: Basel III and Avdjiev et al. 2013, page 39.

The minimum trigger level required for CoCo-bonds to qualify as Additional Tier 1 (AT1) capital is 5,125%, calculated as *Core Equity Tier 1 /Risk Weighted Assets*. The minimum trigger level has become market standard and most banks now issue CoCos with a trigger set at this level. The Basel III framework requires all AT1 instruments to be perpetual. Contractually Norwegian CoCos are indeed perpetual, but historically issuers have called these bonds after 5 years, and this is now what investors expect. A failure to meet this expectation might enhance the perceived risk in these instruments. In Norway CoCos cannot be called prior to 5 years after their issuing date, and the Financial Supervisory Authority of Norway would have to approve any such calling. Furthermore, in Norway all CoCos issued are high trigger contingent securities, and are therefore categorized as AT1 capital instruments.

3.2. A short note on data

We use three types of data in this analysis: (i). Market quotes on CoCo-bond spreads and bank stock prices. (ii). Accounting data in order to model the liabilities side of bank balance sheets. (iii). Riskless interest rates. The data covers the period from July 3 2014 to October 12 2017. Market quotes on CoCos were obtained from Oslo Stock Exhange and Nordic Bond Pricing. Share prices on bank equity were obtained from Oslo Stock Exchange, as was quotes on 3 months NIBOR rates. The CoCos were issued by the two banks under study, SpareBank1 SMN and DNB. Accounting data were obtained from The Brønnøysund Register Centre and the banks' annual reports.

4. Modeling framework

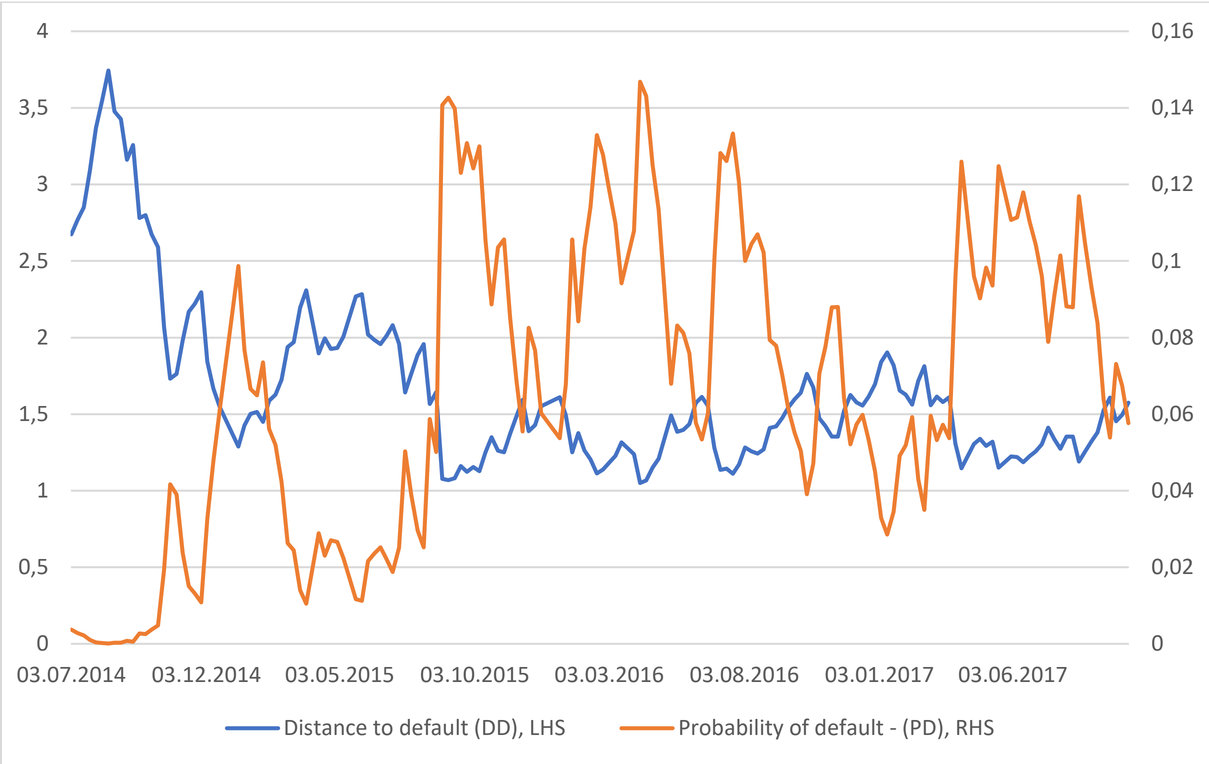
We employ an option pricing approach, a so-called structural model, to assess the theoretical default risk of the contingent convertible bonds of SpareBank1 SMN, the second largest Norwegian savings and loans bank. For comparison we perform the same analysis on the largest Norwegian commercial bank, DNB. This model was pioneered by Robert Merton (1974), who considered owning zero-coupon debt subject to default the equivalent of owning a default free bond and writing a put option on the assets of the firm. In what follows, we shall give a brief account of the Merton model, and continue to describe the assumptions and modifications we have made in implementing the model for the purpose of our analysis.

Assuming that the assets of the firm are lognormally distributed, the Merton model computes the probability that the company will default within a given time period. The original model assumes a simple capital structure with one type of liabilities; a zero coupon bond. The model can easily be extended to account for senior and subordinated debt. We associate three important concepts with the default probability formula:

1. The distance to default, DD, measured in units of standard deviation
2. The default probability, PD
3. The expected recovery rate conditional on default

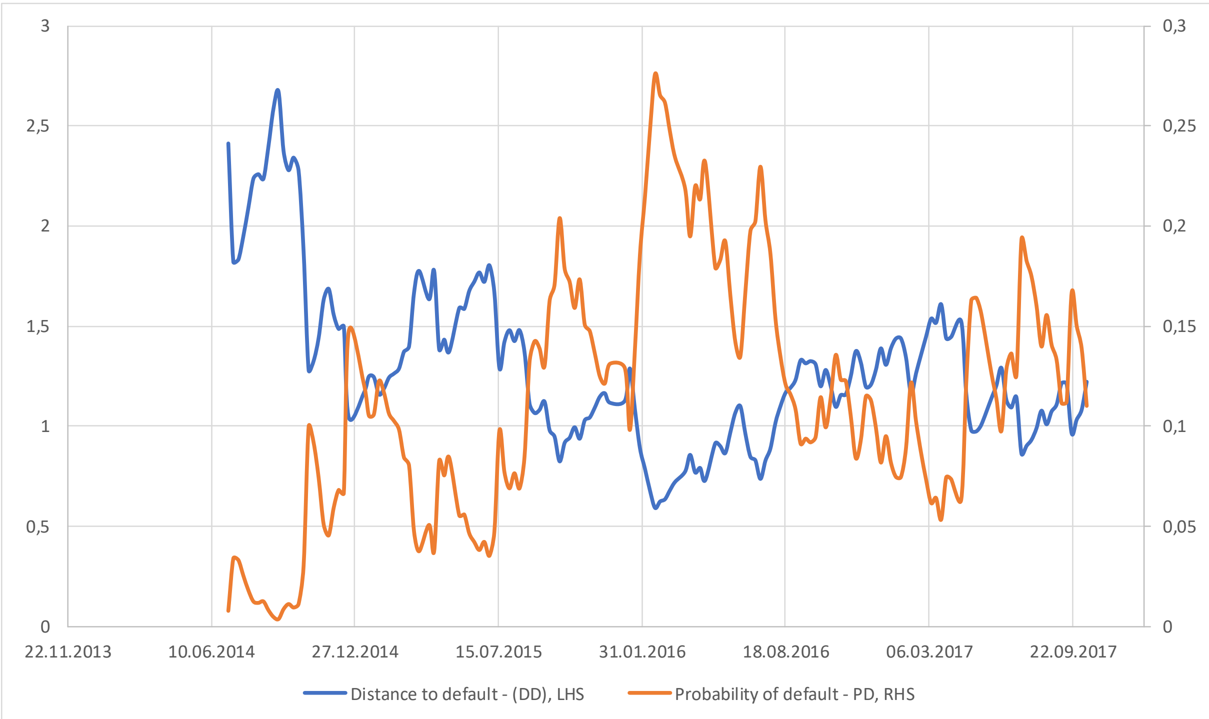
Intuitively an increase in the theoretical distance to default should produce a decrease in the probability of default. This relationship is shown in figure 4.1. and 4.1 for the SMN and DNB CoCo.

Figure 4.1 Model output SMN: Relationship between theoretical distance to default and probability of default



In figure 4.1, PD is the theoretical probability that the trial bank (SMN) will default on its CoCos and DD is the distance to default measured in units of standard deviation.

Figure 4.2 Model output DNB: Relationship between theoretical distance to default and probability of default



In figure 4.2, PD is the theoretical probability that the trial bank (DNB) will default on its CoCos and DD is the distance to default measured in units of standard deviation.

Observe the scale on the right hand side of figure 4.1 and 4.2 above. It is interesting to note that the theoretical probability that DNB, the largest, systemically important bank in Norway might default is larger than the probability that the smaller, regional bank SMN should default. We shall have more to say on this in section 6 below.

The lognormality condition implies that we can assume that the risky assets, A, follow the process

$$\frac{dA}{A} = (\alpha - \delta)dt + \sigma dZ(t) \tag{4.1}$$

or equivalently

$$\frac{dA}{A} = rdt + \sigma dZ^{Q}(t) \tag{4.1.1}$$

Here dA is the instantaneous change in the company's asset value, α is the continuously compounded expected return on the firm's assets, δ is a regular cash payment promised to claim holders of the company and σ is the standard deviation of the instantaneous return on the assets (the volatility). The variables $Z(t)$ and $Z^{Q}(t)$ are normally distributed random variables that follows Brownian motions under empirical and risk neutral (Z^{Q}) probability measures. This implies that $dZ(t)$, which represents the change in $Z(t)$ over a short period of time, has zero mean and a variance of Δt. This further implies that the change in $Z(t)$ over a relatively long period of time T denoted by $Z(T) - Z(0)$, can be regarded as the sum of the changes in $Z(t)$ over *N* small time intervals of length Δt, where $N = \frac{T}{\Delta t}$. We suppose that the *book* value of the firm's liabilities (including accrued interest if any) at the time of maturity T, is denoted by $\bar{L}$.

By construction, the logarithm of the firm's asset value is *normally* distributed, i.e:

$$\ln A_T \sim N\left[\ln(A_t + (\alpha - \delta - 0{,}5\sigma^2)(T-t), \sigma^2(T-t)\right] \tag{4.2}$$

where $N[\bullet]$ represents the cumulative normal distribution function. *The probability of default* at time T, conditional on the value of the assets at time *t*, under the normal distribution is:

$$\Pr\left(A_T < \bar{L} \mid A_t\right) = N\left[-\frac{\ln(A_t / \bar{L}) + (\alpha - \delta - 0{,}5\sigma^2)(T-t)}{\sigma\sqrt{T-t}}\right] \tag{4.3}$$

In the above expression the normally distributed variable, which is the logarithm of the firm's assets, has been standardized by subtracting the mean $(\alpha - \delta - 0{,}5\sigma^2)(T-t)$ and dividing by the standard deviation over the time period considered, $\sigma\sqrt{T-t}$. The default probability $N[\bullet]$ is the probability that a *standard* normal variable $Z(t)$ will incur a value equal to or smaller than $\bar{L}$, in our case the liabilities of the issuer.

The distance to default (DD) is intuitively enough the difference between the expected log asset value at time T, $E[\ln A_T]$ and the bankruptcy level $\bar{L}$ normalized by the standard deviation, i.e., measured in units of standard deviation:

$$\frac{E[\ln A_T] - \bar{L}}{\sigma\sqrt{T-t}}$$

When realizing that

$$E\left[\ln A_T\right] = \ln\left(A_T\right) + (\alpha - \delta - 0{,}5\sigma^2)(T-t) \qquad (4.4)$$

the distance to default becomes:

$$DD = \frac{\ln(A_t/\bar{L}) + (\alpha - \delta - 0{,}5\sigma^2)(T-t)}{\sigma\sqrt{T-t}} \qquad (4.5)$$

which is the term in brackets on the right hand side of equation 4.3 (multiplied by -1). This is *the* crucial measure in an option based structural credit default model. While using structural models as an integral component of the rating process, many rating agencies do not rely on computing theoretical probabilities of default to assign credit ratings to issuers. Instead, they use the distance to default as their theoretical starting point. We will elaborate on this issue in section 4.

The expected recovery rate conditional on default is simply the expected value of the bond if the issuer defaults, relative to the book value (or promised payout) of the bond $\bar{L}$:

$$E(\text{recovery rate}) = \frac{E\left[L_T \mid \text{Default}\right]}{\bar{L}}$$

In the Merton model, the expected recovery *value* is interpreted as the partial expectation of the firm's assets at time T given default, divided by the probability of default:

$$E(A_T \mid A_T < \bar{L}) = A_t e^{(\alpha-\delta)(T-t)} \frac{N\left(\dfrac{\ln(\bar{L}) - [\ln(A_t) + (\alpha - \delta + 0{,}5\sigma^2)(T-t)]}{\sigma\sqrt{T-t}}\right)}{N\left(\dfrac{\ln(\bar{L}) - [\ln(A_t) + (\alpha - \delta - 0{,}5\sigma^2)(T-t)]}{\sigma\sqrt{T-t}}\right)} \qquad (4.6)$$

This is a conditional expectation, i.e., the expected value of the firm's assets *conditional* on default. It is the third crucial relation in the Merton model. The ratio $N[\bullet]/N[\bullet]$ in 4.6 is the recovery *rate*. Observe that the only difference between the expression in the numerator on the right hand side of equation 4.6 and the expression in the denominator is the sign of the σ^2-term. The expression in the numerator (including the exponential that multiplies it), is the partial expectation of the asset value *given* default, conditional on the asset value at time t. It requires a lot more work to arrive at the formula for the partial expectation than calculating the conditional probability in the denominator, which follows directly from the expression for the expected log value of the firm's assets under the normal distribution. We will not go through these tedious calculations in this paper, but rather put the formula to use in the next section.

Extending a loan to a company is subject to credit risk in that default occurs when the bond matures at time T if the value of its assets are lower than the book value of its liabilities, i.e. $A_T < \bar{L}$. Due to the presence of credit risk, the yield to maturity on the firm's debt, i.e. the bond, is greater than the risk free interest rate. This implies that $L_t < \bar{L}e^{-r(T-t)}$, in other words, there is a default spread or *credit spread* compensating bondholders for the default risk they incur.

Under the Black-Scholes option model assumptions the *value of the credit risk* arising from buying the company's debt, is equal to the value of a *put* option on the value of the assets A of the firm, with strike price equal to the liabilities $\bar{L}$. We know this because if the bondholder also buys this put option, her portfolio combining the bond and the put will be risk free. It will yield a payout of $\bar{L}$ irrespective of the value of the firm's assets when the bond matures at time T. The value of the put option is simply the cost of eliminating the credit risk associated with the bond. The put value P_t can be computed from the formula:

$$P_t = \bar{L}e^{-r(T-t)}N[-d_2] - A_t e^{-\delta(T-t)}N[-d_1] \quad (4.7)$$

where

$$d_1 = \frac{\ln(A_t/\bar{L}) + (r + 0,5\sigma^2)(T-t)}{\sigma\sqrt{T-t}} \quad (4.8)$$

$$d_2 = d_1 - \sigma\sqrt{(T-t)} \quad (4.9)$$

Equivalently, in the Merton model, the *equity* E of the firm can be regarded as a *call* option on its underlying assets with strike $\bar{L}$. The value of the equity, or equivalently the call value C_t can be computed from the formula:

$$C_t = E_t = A_t e^{-\delta(T-t)}N[d_1] - \bar{L}e^{-r(T-t)}N[d_2] \quad (4.10)$$

The option formulas in equations 4.7 and 4.10 have intuitive interpretations. Let us rewrite equation 4.10:

$$C_t = E_t = e^{-r(T-t)}\left\{A_t e^{-\delta(T-t)}N[d_1]e^{r(T-t)} - \bar{L}N[d_2]\right\} \quad (4.10.a)$$

The expression $N[d_2]$ is the probability that the option will be exercised in a risk neutral world, so that $\bar{L}N[d_2]$ is the strike price times the probability that the strike price will be paid (in order to obtain the assets of the firm). The expression $A_t e^{-\delta(T-t)}N[d_1]e^{r(T-t)}$ is the expected value of a variable that is worth A_T if $A_T > \bar{L}$ and zero otherwise in a risk neutral world, i.e., the *partial expectation* of the assets given exercise of the call. The put formula 4.10 has a similar interpretation.

The value of the company's assets can easily be deduced from formula 4.10. Assume for simplicity that δ = 0. Then

$$A_t = \frac{E_t + \bar{L}e^{-r(T-t)}N[d_2]}{N[d_1]} \quad (4.11)$$

This means that if we for instance observe the market value of a listed company's equity E_t, we can compute or deduce A_t using the formula in 4.11. Note that the expressions for the value of the firm's equity (the value of the call option) and the value of the assets contain the *risk free* interest rate r and not the drift rate of asset returns α. This is due to the concept of risk neutral valuation of contingent claims. This important property relies on the fact that the Black-Scholes-Merton differential equation, governing the evolution of the option price, does not include any variables that are affected by investors risk preferences. Neither does the option pricing formula, the centerpiece of the Black-Sholes model (1973). When valuing contingent claims, we may thus assume that investors are risk neutral, and that the expected return on all financial assets is the risk free rate of return. For the purpose of our model, this means that we must compute asset values and spreads under a risk neutral probability measure. The only thing this requires is that we adjust our pricing formulas using the risk-free interest rate r rather than the assets drift α. This gives us the following formulas:

$$\Pr\left(A_T < \bar{L} \mid A_t\right) = N\left[-\frac{\ln(A_t/\bar{L}) + (r-\delta-0,5\sigma^2)(T-t)}{\sigma\sqrt{T-t}}\right] \tag{4.12}$$

for the *risk neutral expected default frequency* and

$$E(A_T \mid A_T < \bar{L}) = A_t e^{(r-\delta)(T-t)} \frac{N\left(\frac{\ln(\bar{L}) - [\ln(A_t) + (r-\delta+0,5\sigma^2)(T-t)]}{\sigma\sqrt{T-t}}\right)}{N\left(\frac{\ln(\bar{L}) - [\ln(A_t) + (r-\delta-0,5\sigma^2)(T-t)]}{\sigma\sqrt{T-t}}\right)} \tag{4.13}$$

for the risk neutral expected *recovered asset value*, conditional on default.

We still need to obtain one crucial formula, namely the formula for *the credit spread*. The yield to maturity in our notation is implicitly defined by the formula:

$$L_t = \bar{L}e^{-y(T-t)} \tag{4.14}$$

We noted above that the *value of the credit risk* of the company's debt is equal to the value of a *put* option on the value of the assets A of the firm, with strike price equal to the liabilities $\bar{L}$. This implies that a portfolio of the bond L_t and the put P_t is risk free, i.e., it should yield the risk free rate of return:

$$L_t + P_t = \bar{L}e^{-r(T-t)} \tag{4.15}$$

We can now derive an expression for the yield to maturity. From 4.14 and 4.15 we get:

$$y_{t,T} = -\frac{\ln(L_t/\bar{L})}{T-t} = -\frac{\ln(\bar{L}e^{-r(T-t)} - P_t)/\bar{L}}{T-t} \tag{4.16}$$

The credit spread between time t and T, $s_{t,T} = y_{t,T} - r$, can be derived from 4.16 as the *risk premium* in addition to the risk free interest rate r, by substituting for the put price P_t from equation 4.7:

$$s_{t,T} = -\frac{1}{T-t}\left[\ln\left(\frac{\bar{L}e^{-r(T-t)} - (\bar{L}e^{-r(T-t)}N(-d_2) - Ae^{-\delta(T-t)}N(-d_1))}{\bar{L}}\right)\right] - r$$

$$s_{t,T} = -\frac{1}{T-t}\left[\ln\left(\frac{\bar{L}e^{r(T-t)}N(-d_2) + Ae^{-\delta(T-t)}N(-d_1)}{\bar{L}}\right)\right] - r$$

$$s_{t,T} = -\frac{1}{T-t}\left[\ln\left(N(d_2) + \frac{Ae^{-\delta(T-t)}}{\bar{L}e^{-r(T-t)}}N(-d_1)\right)\right] \tag{4.17}$$

The credit spread $s_{t,T}$ in equation 4.17 is the variable we will compute and evaluate for Norwegian CoCo-bonds, but as we explain in the next section, when implementing the model we use a slightly different spread formula.

5. Implementing the structural model

The Merton model is developed under certain assumptions, all of which do not necessarily hold in the real world. For instance, the model assumes that every individual behaves as if she can buy or sell as much of any security she wishes, without affecting its market price. This condition generally does not hold for NOK denominated CoCos and is one reason why we would expect market spreads to deviate from model spreads. Furthermore, the condition that asset prices are log normally distributed is questioned by many researchers. In terms of corporate asset values in general, we share this criticism.

When applying a Merton style model to corporate credit spreads, one might thus be reluctant to calculate a theoretical default probability using equation 4.12, which does employ the normal distribution. A way out might be the approach employed by Vasicek and Kealhofer (2003), when building a structural model of default risk that has become known as the KMV model. They compute distances to default for 420.000 US companies using equation 4.5, and observe empirical or historical default frequencies of (groups of) firms sorted by their different distances to default measures. In this manner they obtain an empirical mapping between distance to default and default frequency.

The KMV procedure requires a huge amount of company data, in order to calculate reliable *empirical* default distributions. For instance, among the 420.000 companies under study, 4.700 hundred credit events (or technical defaults) were recorded. This strategy would be impossible to apply to Norwegian banks, which rarely default on their liabilities and even more rarely goes bankrupt. We do however believe that the log normality assumption of company assets might be more reasonable for bank assets than corporate assets, since banks' balance sheets are far more diversified than corporate balances. Consequently, in our view the justification for computing theoretical default probabilities using equation 4.12 is stronger when dealing with bank debt than corporate liabilities.

Successful implementation of the model requires that the real world counterparts of the model-components, can be directly observed or estimated form observable variables. We will now explain how we have defined and calculated the variables that go into equation 4.12. Basically these are: Asset value at time t A_t, the liabilities of the issuer $\bar{L}$ and asset volatility σ^2.

Asset volatility is a central parameter in structural models of credit spreads. The volatility of a firm's total assets is not directly observable, and may be modelled by the formula:

$$\sigma^2 = (1-L)^2\sigma_E^2 + L^2\sigma_D^2 + 2L(1-L)\sigma_{ED} \tag{5.1}$$

where E denotes equity and D denotes debt. L denotes leverage and is the ratio of debt to equity. Correira et. al. (2014) evaluate alternative measures of asset volatility combining information from historical returns, implied volatilities from options on stocks, and financial statements. They find that their approach generates superior forecasts of bankruptcy for US issuers.

In constructing the volatility of the bank's assets we follow Feldhütter & Schaefer (2016). Initially we assume the volatility of the debt is zero, compute the volatility of the listed equity values σ_E^2 and adjust for leverage multiplying by $(1-L)$. The resulting expression $(1-L)^2\sigma_E^2$, a lower bound for asset volatility, is multiplied by a scalar that depends on the leverage ratio L. If L > 0,75 Feldhütter & Schaefer multiplies this expression by 1.8. Of course, bank liabilities are just means to financing bank assets, and the discounted flow of interest payments on that debt is part of the liabilities. Since the debt is regularly being refinanced, the interest payments are stochastic. Thus in reality, bank liabilities are volatile. For the banks we are analyzing, the debt value is always higher than 75 percent of total assets. Our expression for asset variance becomes:

$$\sigma^2 = 1.8(1-L)^2\sigma_E^2 \tag{5.2}$$

Equity volatility may be computed from observed time series data of equity return. We wish to compute an annual volatility measure for σ_E^2 based on a 250 days rolling window. For each day we compute a daily volatility measure from the formula:

$$\sigma_t^2 = \lambda\sigma_{t-1}^2 + (1-\lambda)r_t^2 \tag{5.3}$$

where σ_{t-1}^2 is the daily volatility of return at time t-1, r_t^2 is the daily squared return at time t, i.e., the time t variance, and λ is a scalar such that $0 < \lambda < 1$. We obtain a rolling, annual volatility measure for σ_E (a standard deviation) based on a 250 days rolling window from the formula:

$$\sigma_E = \sqrt{250\sigma_t^2} \tag{5.4}$$

The annualized *average* volatilities of DNB's and SpareBank1 SMN's equity returns for the period December 2013 – November 2017 are *24% and 22%* respectively.

Having determined the expression for asset volatility, we turn to the capital structure of the bank's liabilities. As explained in section 3, CoCo-bonds are hybrid convertible securities that absorb losses when the equity capital of the issuing bank falls below a predetermined threshold. This threshold is the model default point. In order to calculate the default risk in CoCos, we need to define and calculate the *trigger level* associated with the default point. We define the trigger as a mechanical rule activating the loss absorption mechanism, when the capital of the issuing bank falls below a pre-specified fraction of its *risk weighted assets* (RWA). The "real" default point is adjusted so that it lies at the point where the issuing bank's Core Equity Tier 1 Capital (CET1) equals 5,125 percent of RWA. This is obtained by reducing the book value of the total debt by an amount equal to 5,125 percent of RWA. Total assets A_t are then modeled as the sum of listed equity and the trigger adjusted book value of debt $\bar{L}$. This is how the variables that goes into the fraction $\ln(A_t / \bar{L})$ in equation 4.12 are calculated. The distance to default, DD, then becomes the distance to the trigger level of the CoCos, i.e., the distance to default on the CoCos.

In addition, we have slightly amended the credit spread formula 4.17, when implementing the model. Here we follow Chen et al. (2009), who derive a useful expression for the credit spread. They show that the risk-neutral probability-measure π^Q that we need for pricing purposes, can be expressed in terms of the historical probability-measure π^P. (These are the two probability-measures that we used in equation 4.3 and 4.12). Their formula is:

$$\pi^Q = N[N^{-1}(\pi^P) + \theta\sqrt{T-t}] \tag{5.5}$$

where θ is the sharpe ratio $(\mu - r)/\sigma$ and N is the normal cumulative distribution. The credit spread is:

$$s_{t,T} = y_{t,T} - r = -\frac{1}{T-t}\ln\left[1 - L\pi^Q\right] \tag{5.6}$$

In this expression, L is the historical loss rate. Combining 5.5 and 5.6, the authors obtain a nice expression for the credit spread:

$$s_{t,T} = y_{t,T} - r = -(\frac{1}{T-t})\ln\{1 - L\,N[N^{-1}(\pi^P) + \theta\sqrt{T-t}]\} \tag{5.7}$$

Equation 5.7 expresses the credit spread in terms of the expected default rate π^P, the historical loss rate L and the Sharpe ratio θ. Applying this formula, we may use historical market estimates for Sharpe ratios and recovery rates. We are now ready to put the model to work.

Results

Our objective is twofold: (i) We want to examine if our model can explain and replicate observed CoCo-bond spreads in the Norwegian securities market. We study CoCos issued by two different banks: the second largest Norwegian savings and loans bank, SpareBank 1 SMN and the largest Norwegian commercial bank, DNB. (ii) We also seek to find out if CoCos offer a relatively cheap funding opportunity for banks compared to equity capital.

Our reference time series, which we compare to the model credit spreads, are actual spreads on four different *NOK denominated* CoCos issued by SMN and, and two different *NOK denominated* CoCos issued by DNB, which are traded in the Norwegian secondary market. DNB also issues USD denominated CoCos. However in order to compare securities denominated in foreign currencies to NOK denominated securities, their spreads must be hedged into NOK through the basis swap. The USD/NOK basis swap is influenced by many factors including US monetary policy, which would make our results harder to interpret. Concequently we only consider NOK denominated CoCos.

We obtain weekly quoted *spreads to 3 month NIBOR* on four different perpetual SMN-CoCos. Two of these contracts will nevertheless be called in 2018 and the remaining two in 2020. This is established market practice even if the contracts stipulate that the bonds are perpetual. The four spread series are weighted together in an average series such that the weights reflect remaining outstanding volume in each contract, relative to the sum total amount outstanding. This series is depicted as the blue line in figure 6.1 labeled "SMN weighted spread (3M NIBOR)". The maturity on this weighted average series declines as we approach the call date, and the spread is calculated as spread to call. Hence the spread itself declines because the pull to par effect becomes stronger as the bond approaches maturity.

Similarly we obtain weekly quoted *spreads to 3 month NIBOR* on weighted perpetual DNB-CoCos. This series is depicted in figure 6.1 as the *combined* black and green line labeled DNBA59 weighted spread (3M NIBOR) *and* DNBA59 spread (3M NIBOR). The reason these two series have been combined into one is that prior to June 30 2016 this series consisted of only one CoCo-bond, but was subsequently converted to a weighted index consisting of two CoCos.

Figure 6.0 illustrates the high beta nature of CoCo's represented by spread and price movements of the perpetual CoCos of Norway's largest commercial bank, DNB. The spread widening in early 2016 was most likely due to worries about Deutsche Bank, and the coupon risk inherent in the product, and also reflected the possibility that the bonds would not be called. DNB's perpetual CoCos were negatively affected by market sentiment, and the banks' Treasury department had to convince investors that the coupons were not at risk in order to calm the market. The inherent coupon risk in CoCos is real, but regulators have defined a Maximum Distributable Amount (MDA) where the coupon is at risk. In our view, coupon risk is generally not a concern for CoCo investors, and the credit spread should reflect the trigger point at which the nominal value of the instrument will be written down.

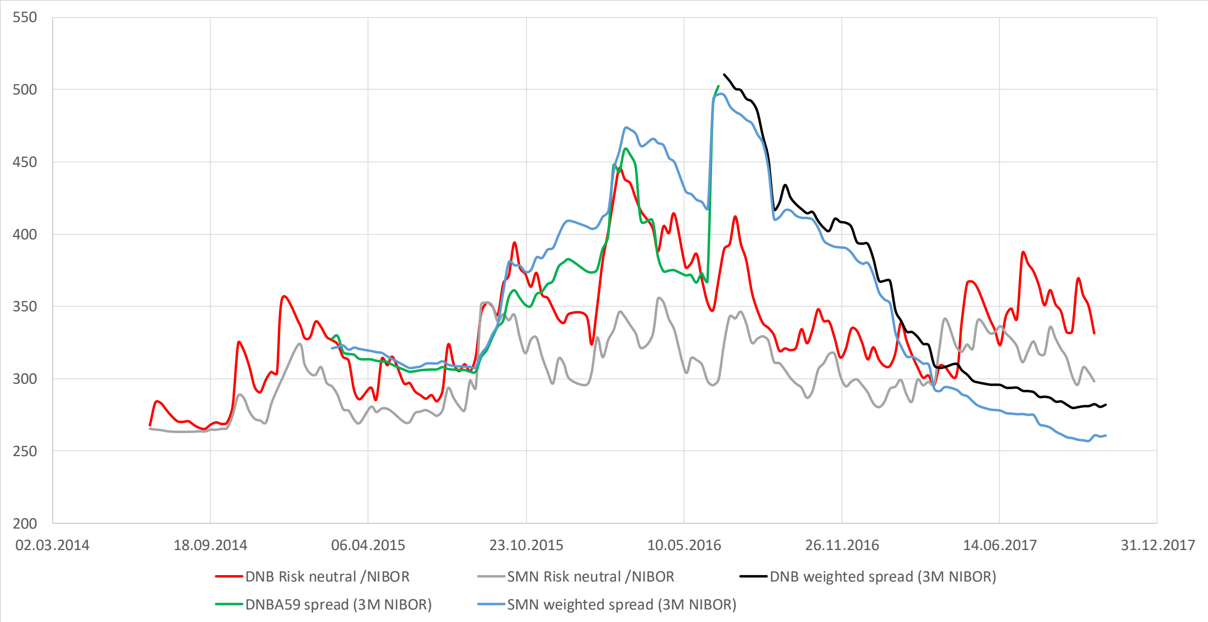
Figure 6.0. DNB 5.75 perpetual CoCo-bond. Spread to 5 year call vs. price. Face value 100.

Source: Bloomberg

For illustrative purposes figure 6.0 shows a USD denominated DNB CoCo.

The quoted market spreads are compared to spreads computed by the credit default model. The model spreads are depicted in figure 6.1 by the red and grey lines. The red line labeled “DNB Risk neutral/NIBOR” is the model DNB-CoCo spread to 3 months NIBOR. Analogously, the grey line labeled “SMN Risk neutral/NIBOR” is the model SMN-CoCo spread to 3 months NIBOR.

Figure 6.1. Model spreads versus market spreads on Norwegian CoCo-bonds

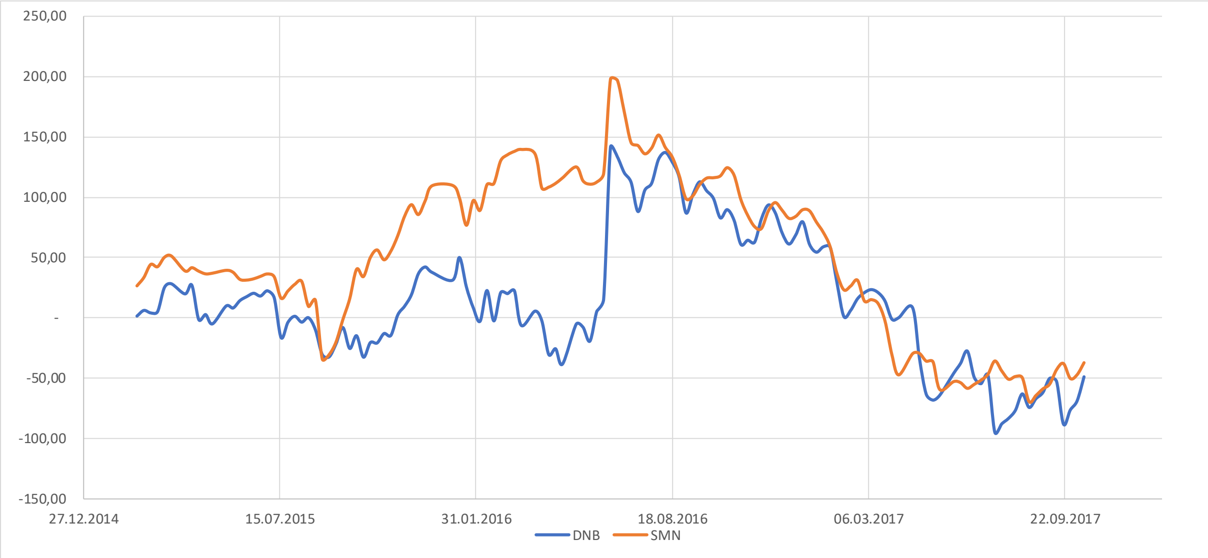


Several features of actual market spreads and theoretical model spreads can be discovered from studying figure 6.1. In general the model underestimates observed spreads, but there are periods where the model produces higher spreads than observed market spreads. The model captures the volatility of spreads fairly well.

The *level* of model spreads are sensitive to the volatility of assets. The shape of the series are not. If we increase/decrease asset volatility by an arbitrary scalar, the scale in figure 6.1 is changed, but the shape of the model series stays the same. Nevertheless, the volatility of the value of the assets of the issuing company is a crucial model parameter, and it is difficult to estimate it correctly. This is a major concern when applying structural models. A lot of effort should go into getting this parameter right.

When oil prices started to decline in the middle of June 2014, market spreads on CoCo-bonds began to widen. Still market spreads were relatively close to model spreads until late fall 2015, when they in earnest started to rise above model spreads. Over the next two years, both SMN and DNB market spreads were significantly higher than model spreads. SMN CoCo market speads peaked the end of June 2016 at 197 basis points above model spreads whereas DNB CoCo market spreads peaked by mid August 2016 at 137 basis points above model spreads (figure 6.2). Since March 2017, market spreads appear to stay closer to model spreads. We can interpret these observations by a combination of economic and technical reasoning.

Figure 6.2 Deviation of Merton models spreads from CoCo market spreads



The period after the huge decline in oil prices in 2014 has been a challenging time for several key sectors in the Norwegian Mainland economy, including the entire supply chain to the oil sector. Although low by international standards unemployment started to rise and came close to 5 percent in the third quarter of 2016. Obviously Norwegian banks have extended loans to companies in sectors which were negatively affected by the decline in investments following the slump in oil prices. In such a nervous environment, *liquidity* premiums in bond markets soar. The risk measure in the Merton model in our implementation does not explicitly take account of liquidity premiums, unless of course poor liquidity is reflected in increased volatility of assets. We believe that higher liquidity premiums account for a substantial part of the difference between market spreads and model CoCo-bond spreads in the period between late fall 2015 and March 2017.

If failure to take account of liquidity premiums is an explaination for the credit spread puzzle, we would expect Merton model spreads to stay closer to observed market spreads the more liquid are the CoCos. This is confirmed by figure 6.2. The DNB CoCo is far more frequently traded at higher volumes in the secondary markets than the SMN CoCo, i.e., it is more liquid and requires a smaller liquidity premium. Consequently the difference between model and market spreads are smaller for the DNB CoCo compared to the SMN CoCo.

During 2017 the Norwegian economy has recovered, unemployment is declining and investments in the oil sector is expected to pick up, feeding positively into the Mainland economy. For most part of 2017 model spreads stay closer to market spreads as depicted by the red and blue lines in figure 6.1. In January 2018 SpareBank 1 SMN issued a new AT1 CoCo in NOK, with 5 years to call. This bond offered 3 month NIBOR plus 310 basis points, which is fairly close to what the model would predict. In 2018 securities markets have become more volatile and CoCo spreads have widened.

On a technical note, as we would expect, model spreads are slightly above market spreads to NIBOR even in the booming 2017 financial markets.is This is because the CoCos, as we explained above, are pulled to par as we approach the call dates. Yet, more importantly, in bullish financial markets, which we have experienced in 2017, liquidity premiums are less of an issue and in this environment the Merton model seems to produce credit spreads fairly close to observed market spreads.

6.1. CoCo funding versus equity capital

In the introduction to this paper we said that we wanted to examine if CoCo-bonds offer cheap funding for banks relative to equity capital. How should we compare CoCo-bond spreads to return on bank equity capital? We might for instance find from studying historical data that the average risk premium on the S&P 500 equity index over a very long time period (100 years?) is about 3,5 percent. In theory this might be considered a measure of the cost of equity for US companies. Still, which we explain shortly, we question whether this measure is correct even in theory. More importantly, it is rare to obtain time series data on Norwegian individual company stocks dating back more than 20-30 years.

A viable approach might be calculating the average cost of issuing equity capital relative to a measure of the risk free interest rate over a given period, and compare this cost to average Coco spreads in the same period.

Figure 6.3 Annualized return on SpareBank1 SMN equity

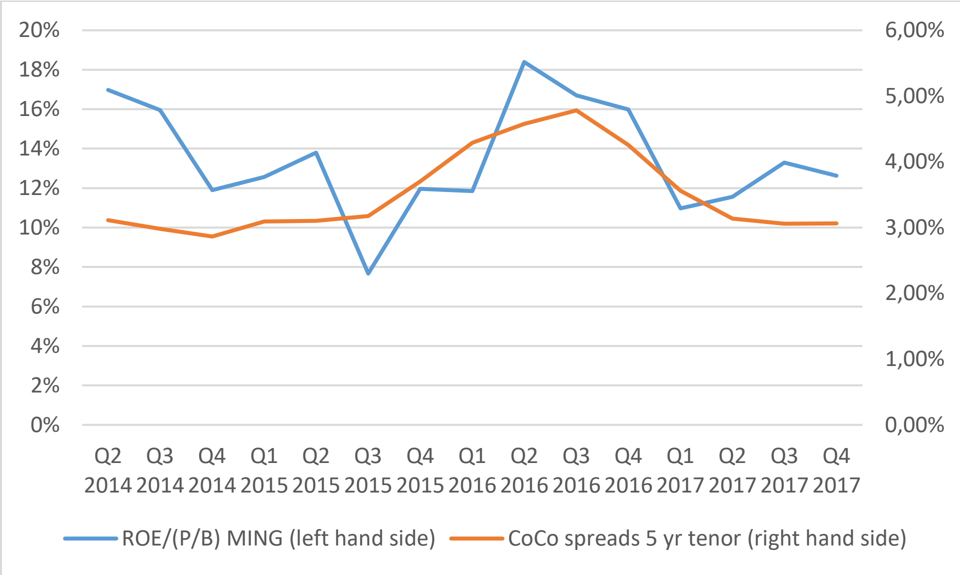
Source: Bloomberg

If we look at figure 6.3, which depicts annualized return on SMN equity, we immediately realize that we cannot use this return series directly to compare the cost of issuing equity capital to the cost of issuing debt. A depiction of the annualized return on the DNB equity would give the same conclusion. Issuing equity capital is a strategic decision which entails many considerations, including determining whether the company needs more capital at a particular point in time, and equally important deciding when to issue shares, i.e., market timing. Companies often defer issuing equity capital until equity market conditions are benevolent in order to avoid diluting existing shareholders.

What we ideally need is a company record of historical costs of equity issuances. Unfortunately, these data are not available for most banks in the SME segment, but we may compute the cost of equity indirectly from the firm's return on equity, ROE. Usually, this key figure may be found in banks' quarterly and annual reports. Return on equity (ROE) will be affected by accounting measures, so ideally we need to adjust this measure in order to obtain a normalized ROE. This means that we should take account of non-recurring items such as profit and loss from investments, changes in pension schemes and other adjustments. We have not attempted to adjust our measure for the cost of equity for such items, as this would be prohibitively time consuming and in practice not possible.

As a proxy for the cost of issuing equity, we simply compute the ratio of return on equity to price/book; ROE/(P/B). We only apply this model to the SMN equity. Observe that when the price/book measure equals one, the cost of issuing equity equals the accounting item ROE. When price/book exceeds one, the cost of issuing equity decreases reflecting increased expected future cash flow. When the share price is less than the book value per unit of capital, the cost of issuing capital exceeds the accounting ROE.

Figure 6.4. Cost of issuing SMN equity capital versus spreads on SMN CoCo-bonds (observed quarterly)



Source: SpareBank1 SMN

Figure 6.4 suggests that spread movements on CoCos issued by SMN are related to movements in the expected implied return on its equity. When equity investors are highly risk averse, i.e., demand high return on equity, the spread on the CoCos are also high. It is also evident that spreads on CoCos are nowhere near the implied cost of equity capital. CoCos are far cheaper even after subtracting a (historic) risk premium on equity capital of 3-5 percent.

The most important job for a bank considering how to comply with the capital requirements imposed by regulators is to minimize the cost of capital. Banks are allowed to use CoCos in the amount of 1,5 percent of total capital requirement. Not only are CoCos cheaper than equity capital, issuing shares also has the disadvantage of diluting exciting shareholders. Issuing shares might be an efficient means of funding profitable growth, but issuing shares in order to comply with capital requirements is not preferable if there are alternative sources of capital, because this means that the issuer will increase the number of outstanding shares without increasing earnings. Banks will always attempt to minimize the cost of funding their balance sheets, and thus should employ the maximum permissible amount of CoCo-bonds.

On the demand side CoCos, although hybrid equity capital, are viewed as fixed income securities rather than shares by investors. Bond investors are less concerned with banks' growth stories than are equity investors. Legislative changes made to CoCos in 2013, made these instruments look even more like shares. Banks no longer have any direct incentive to call these loans (although this is market standard) and investors might lose the coupon. Still, in a default situation insolvency rules ensure that CoCos are less risky than equity.

6. Concluding remarks

In this paper, we have modeled and examined spreads on perpetual contingent convertible high trigger bonds (CoCos), issued by SpareBank 1 SMN, a Norwegian savings and loans bank. For comparison, we also studied similar CoCos issued by the largest Norwegian commercial bank, DNB. Although formally the bonds are perpetual, they are callable after five years subject to permission by the Financial Supervisory Authority of Norway, Finanstilsynet. Using a Merton style structured option modeling approach, we attempt to capture CoCo-bond spreads during the period from June 3 2014 until October 26 2017. We find that model spreads are narrower than market spreads in periods of market distress. This is precisely when liquidity vanishes from Norwegian bond markets, and liquidity premiums, which most structural models do not capture, soar. On the contrary, the model produces spreads which are fairly close to observed market spreads, when market conditions are benign and liquidity is less of a concern. We also note that the Merton model is overly sensitive to the numerical value "assigned to" the volatility parameter.

The DNB CoCo is far more frequently traded at higher volumes in the secondary markets than the SMN CoCo. It is therefor more liquid and should require a lower liquidity premium. Figure 6.2 confirms that the difference between model and market spreads are smaller for the DNB CoCo compared to the SMN CoCo.

When comparing CoCo-bond spreads to the cost of issuing equity capital, we find compelling evidence that CoCos offer cheap funding for the bank. We might also further *speculate* that without the cushion offered by CoCo capital, the average cost of equity capital will increase even if the CoCos were replaced by alternative securities, which require the application of a statutory resolution regime in order to absorb losses. CoCo-bonds are of course more expensive for the issuing bank than subordinated and senior bank bonds. However, these securities do not compete with CoCos because, apart from equity, only CoCos are eligible to comply with capital adequacy requirements. Banks will always attempt to minimize the cost of funding their balance sheets, and should employ the maximum permissible amount of CoCo-bonds.

References

Arora, N., Bohn, J. R., Zhu, F. (2005) Reduced Form vs Structural Models of Credit Risk: A Case Study of Three Models.
https://pdfs.semanticscholar.org/2231/c28ddf67cc8a199bd10aa5040ef1bf39350f.pdf

Avdjiev, S., Bolton, P., Jiang, W., Kartasheva, A., Bogdanova, B. (2015) CoCo-bond Issuance and Bank Funding Costs. Conference on Financial Regulation, Becker Friedman Institute, University of Chicago, October 2-3, 2015

Avdjiev, S., Kartasheva, A., Bogdanova, B. (2013) CoCos: a primer. *BIS Quarterly Review*.

Black, F and Cox, J. (1976) Valuing Corporate Securities: Some Effects of Bond Indenture Provisions. *Journal of Finance*, 31, 351-367

Black, F. and Scholes, M. (1973) The Pricing of Options and Corporate Liabilities. *Journal of Political Economy*, 81: 637-659

Chen, L., Collin-Dufresne, P., Goldstein, R. S. (2009) On the relation between the credit spread puzzle and the equity premium puzzle. *Review of Financial Studies, 22*, 3367–3409.

Correira, M., Kang, J., Richardson, S. (2014) Asset Volatility. Working Paper.

Crouhy, M., Galai, D., Mark, R. (2001) Risk Management. McGrow-Hill, ISBN 978-0-07-137867-7

Feldhütter, P. and Schaefer, S. (2017) The Myth of The Credit Spread Puzzle. *Review of Financial Studies*, forthcoming

Hull, J., White, A. (1995). The impact of default risk on the prices of options and other derivative securities, *Journal of Banking & Finance*, 19-(2), 299-323.

Hull, J., White, A. (2000). Valuing credit default swaps 1: No counterparty default risk, *Journal of Derivatives*, 8-(1), 29-40.

Kealhofer, S. (2003). Quantifying Credit Risk I – Default Prediction. *Financial Analysts Journal*, January/February, 1.

Kealhofer, S. (2003). Quantifying Credit Risk II – Debt Valuation. *Financial Analysts Journal*, May/June, 3.

Marin, J. and Ponce A. (2005) Structural Models and Default Probability: Application to the Spanish Stock Market. *Investment Management and Financial Innovations*.

Merton, R., 1974, On the Pricing of Corporate Debt: The Risk Structure of Interest Rates, *Journal of Finance*, 29, 449-70.

Sæbø, J. K (2011) Risikopremier i Norsk Kreditt. Temaartikkel, Folketrygdfondet.

Sæbø, J. K (2015). The Credit Spread Puzzle Does Exist—*But Is It Really a Puzzle? The Journal of Fixed Income* Summer 2015, 25 (1) 75-83; DOI: https://doi.org/10.3905/jfi.2015.25.1.075