

Contingent Capital: The Case of COERCs

by

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Abstract

This paper introduces, analyzes, and values a new form of contingent convertible (CoCo) bond, a Call Option Enhanced Reverse Convertible (COERC). If an issuing bank's market value of capital falls below a trigger, COERC investors would be issued many new equity shares that would heavily dilute the bank's existing shareholders, except that shareholders have the option to purchase these shares at the bonds' par value. COERCs have low risk since investors are almost always repaid in cash, yet they reduce government bailouts by replenishing the bank's equity capital following a decline. The COERC design also avoids problems with market-based triggers such as manipulation by speculators or "death spirals" due to an unjustified panic. Relative to standard CoCos or non-convertible subordinated debt, COERCs reduce a bank's incentive to choose investments that are subject to large losses, and they also mitigate "debt overhang."

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1. Introduction

This paper introduces, analyses, and values a new security named a Call Option Enhanced Reverse Convertible or COERC. It is a variant of contingent capital (also called contingent convertibles or CoCos) that addresses many of the criticisms made against standard forms of contingent capital. CoCos are bonds that convert to equity after some triggering event, such as a decline in a bank's capital below a threshold. Interest in CoCos has grown since the 2007-2009 financial crisis because other debt-like forms of bank capital such as "subordinated debt and hybrid capital largely failed in its original objective of bearing losses" (HM (UK) Treasury (2009)).

Under Basel III, the Basel Committee on Banking Supervision (BCBS) (2011) requires that for any non-common equity capital to qualify as Tier 1 or Tier 2 regulatory capital, it must be either converted into common equity or written off at the "point of non-viability," defined as the time when a bank is unable to support itself and a government resolution and/or public capital injection is imminent. Such regulatory capital instruments are referred to as "bail-in" debt or "gone-concern" CoCos. It may be unsurprising that Basel III has required that capital must "absorb losses," since prior to the crisis banks' subordinated debt was thought to have this feature.

In contrast, most academic research, including the original CoCo proposal by Flannery (2005), envisions CoCos that convert well in advance of the "point of non-viability" while the bank is still a going-concern. The potential benefit of "going-concern" CoCos is that when a bank's initial equity capital is depleted, the bank automatically recapitalizes, thereby reducing the likelihood of financial distress and a government bail-out. While the BCBS (2011) decided that such "going-concern" CoCos would not be permitted to fulfil the additional capital required of global systemically important banks (G-SIBs), it continues to review such CoCos and does support their use to meet higher national capital requirements. Switzerland has taken the lead by requiring its two major banks, UBS and Credit Suisse, to raise their capital ratios to 19% with up to 9% of this requirement being met with CoCos. A primary reason why the BCBS failed to strongly endorse going-

concern CoCos was the BCBS's expressed uncertainty on how they would perform and how they should be best designed (BCBS (2011, p.18-19)).

One critical feature of going-concern CoCos is the nature of the conversion trigger. To date, the banks that have issued CoCos, including Lloyds, Credit Suisse, UBS, and Barclays, have tied conversion to a regulatory capital ratio. These banks' CoCos would convert if the bank's Tier 1 common equity ratio falls below either 7% or 5%. In contrast, most academic proposals for CoCos envision linking conversion to a market-based measure, such as the bank's stock price or a market value of capital ratio.¹

The choice of a regulatory capital ratio trigger or a market-based capital ratio trigger is important for whether a conversion will occur. Haldane (2011) documents that regulatory capital ratios, in contrast to market capital ratios, failed to forecast the financial crisis. Figures 1.A and 1.B (Chart 5 and 7 from Haldane (2011)) show the Tier 1 capital ratios and market capital to book value of debt ratios, respectively, for two groups of major financial institutions: 15 "crisis" banks that in the autumn of 2008 failed (or required government support or were taken over in distressed circumstances) and 18 "no crisis" banks. While in Figure 1.A the average Tier 1 capital ratios for both groups remained stable and indistinguishable from May 2002 until November 2008, Figure 1.B shows clearly that market capital ratios of crisis banks anticipated their financial distress. Moreover, the market capitalization of crisis banks was much lower than that of no crisis banks, and the gap widened with the approach of the crisis. Hence, if the crisis banks had issued a going-concern CoCos with a regulatory capital trigger, conversion would not have occurred when it was most needed. Market value-based triggers, however, would have led to conversions.

The opposite signals provided by regulatory and market capital ratios are not surprising since banks can more easily control the former: portfolio reallocations can reduce the

¹ Recent academic research on CoCos include Albul et al. (2010), Barucci and Del Viva (2011), Berg and Kaserer (2011), Bolton and Samama (2010), Calomiris and Herring (2011), Flannery (2009a, b), Glasserman and Nouri (2010), Hilscher and Raviv (2011), McDonald (2010), and Squam Lake Working Group (2009).

ratio's risk-weighted asset denominator; and recognizing capital gains via selling assets that have appreciated in value while holding on to assets that have depreciated will increase the ratio's numerator. Merrouche and Mariathasan (2012) document evidence that capital ratios become subject to manipulation in the vicinity of financial distress, and banks that are more likely to receive public aid manipulate risk weights more severely. Because of such manipulation, regulatory capital ratios can be unreliable measures of a bank's financial distress.² Hence, most academics and some regulators have embraced market-based triggers (Haldane 2011).³

However, market-based triggers have also been criticized due to concerns of “death spirals.”⁴ As we detail below, a market-based trigger can create an incentive for speculators to short the bank's stock and force economically “unjustified” conversions and dilution. Moreover, even without short-sellers, issuers are concerned about unjustified conversions created by an irrational market panic. Another concern, analyzed extensively by Glasserman and Nouri (2012), is that market-based triggers may lead to a “multiple equilibria” problem or a “no-equilibrium problem” where the bank's stock value is ill-defined and, hence, may be an unreliable trigger.

The purpose of this paper is to contribute to the CoCo literature by proposing a new design, the COERC. COERCs have two main features that distinguish them from other CoCos, and these two characteristics address criticisms of standard CoCos with market value triggers. First, if conversion is triggered by a decline in the market value of the bank's capital, a relatively large number of new shares would be issued to COERC investors such that the bank's shareholders would tend to be heavily diluted. In other words, the market value of new shares issued to CoCo investors would very likely exceed

² A more recent case is Dexia, the French-Belgian bank that, before being rescued by the government in October 2010, reported a Tier1 ratio above 10% and was ranked 12th out of 90 banks that were subject to stress tests in the Spring of 2010 (De Groen (2011)).

³ Alternatively, regulators, realizing the problem with regulatory capital ratio triggers, may want to pull the trigger themselves. This, however, makes valuing CoCos difficult as investors and credit rating agencies may find it all but impossible to estimate this “regulatory risk.” See “Credit Suisse CoCo Investors Uncertain How to Value Notes” *Financial Times* April 15, 2011.

⁴ See Hillion and Vermaelen (2004), “Stability Concerns over CoCo Bonds” *Financial Times* November 5, 2009, and “CoCo Trigger Plan Draws Wary Response” *Financial Times* April 4, 2011.

the bonds' par value, giving investors a capital gain and the bank's existing shareholders a capital loss. However, the second main feature of COERCs allows shareholders to avoid this dilution because they are given the right (option) to purchase the newly issued shares at an exercise price equal to the COERC bonds' par value.

The proposed COERC design reconciles the conflicting objectives of issuers, regulators and CoCo bond investors. First, its trigger is based on a market value capital ratio rather than a regulatory capital ratio. Second, although based on market values of capital, the design avoids one of the main criticisms of market-based triggers: conversions due to manipulation or panic that would harm the bank's initial shareholders. That is because shareholders have the option to buy the newly-issued shares from COERC investors at the conversion price, with the proceeds repaying the par value of the COERC bond. Third, by setting the conversion price significantly below the trigger price, the COERC is relatively easy to value due to its low risk. Indeed, when the conversion price is significantly below the trigger price, shareholders have a large incentive to prevent dilution by repurchasing the new shares at the COERC bond's par value. This low risk should improve the COERC's liquidity, minimize the likelihood of financial distress, and make it appealing to many fixed-income investors. Fourth, our design implies no role for regulators in pulling the trigger, which eliminates regulatory risk.

Fifth, by basing the trigger on a market value capital ratio (defined as the sum of the market values of equity plus COERCs, divided by senior debt), we avoid multiple-equilibria or no-equilibrium problems that would occur if the trigger were based solely on equity values. Last but not least, although COERCs are generally not loss absorbing, they encourage banks to issue equity and repay debt when in financial distress.⁵ Because this commitment is made ex ante, shareholders benefit through lower borrowing rates and conflicts between shareholders and debt holders are minimized.

⁵ Note that regulators and taxpayers should be indifferent whether the debt holders have to absorb a loss or are "bailed out" by equity holders. In both cases taxpayers do not incur a loss.

The next section provides more specifics regarding the COERC design and gives a simple numerical example of how they would work. Section 3 describes a structural credit risk model of a bank that is used to compare the value and risks of standard CoCos, COERCs, and non-convertible subordinated debt. The results from calibrating this model to data on three large U.S. bank holding companies are given in Section 4. Section 5 extends the basic model to consider imperfect information that can allow the market values of bank stocks and bonds to deviate from the fundamental values of the bank's underlying assets, as might occur due to speculative manipulation of stock prices or an unjustified investor panic. This model generalization permits us to analyze how CoCos, COERCs, and bank shareholders' equity are affected by deviations of market prices from fundamentals. Section 6 discusses further practical issues relevant to CoCos and COERCs, while Section 7 concludes.

2. Call option enhanced reverse convertibles (COERCs)

This section illustrates the basic features of a COERC with a numerical example. The example makes several strong assumptions that are relaxed in the following section where we analyze COERCs, standard CoCos, and non-convertible subordinated debt using a more explicit valuation model.

Assume at some initial date 0 that the market value of a bank's assets, A_0 , equals \$1,100. The bank's liabilities consist of senior deposits, COERCs, and shareholders' equity with market values D_0 , V_0 , and E_0 , respectively. It is assumed that D_0 equals the deposits' par value of \$1,000 and that V_0 equals the COERCs' par value of $B = \$30$. Finally, the initial market value of shareholders' equity is $E_0 = \$70 = S_0 \times n_0$, where $S_0 = \$10$ is the initial stock price and $n_0 = 7$ is the initial number of shares outstanding. Note that, per definition, the sum of the market value of the COERC and the market value of equity is equal to $E_0 + V_0 = A_0 - D_0 = \$100$. We will refer to this sum as the market value of the bank's capital.

If at any date t prior to the COERC's maturity, the market value of capital, $E_t + V_t = A_t - D_t$, falls from its initial value of \$100 to \$65 or less, the COERC's conversion is triggered.

Equivalently, if we subtract off the COERC's par value of $B = \$30$, we can think of conversion being triggered when the value of initial shareholders' equity is $\$65 - \$30 = \$35$ or the equity-to-deposit ratio is 3.5%. However, we specify the trigger as a function of the value of the bank's total capital (equity plus COERCs) for two reasons that are explained further below. First, it discourages stock price manipulation to force conversion and, second, it avoids equilibrium problems when the trigger is based only on equity values.

The COERC is designed so that when conversion is triggered, COERC investors receive a large number of shares, say n_1 , that have the potential to heavily dilute the bank's initial shareholders. In this example, assume $n_1 = 30$. Thus, since the COERC's par value is $B = \$30$, the "conversion price" is set at \$1. That gives COERC investors a share of total capital equal to $\alpha \equiv n_1 / (n_0 + n_1) = 30/37$. If at conversion the total capital of the bank is \$65, then COERC investors would receive $\alpha \times \$65 = \$52.70$ and the price per share would be $\$65/37 = \$1.76$. Hence, the initial shareholders' value would equal $7 \times \$1.76 = \$12.30$.

However, another feature of the COERC is that when the market value of the capital hits the trigger, a rights issue is announced inviting the existing shareholders to buy the 30 new shares at the \$1 conversion price, with their new funds used to repay the COERC debt at its par value. Rational investors will exercise this option since the fully-diluted stock price of \$1.76 is higher than the rights issue price of \$1. If the banks' initial shareholders are financially constrained, they can sell their rights to other non-constrained investors. Consequently, the COERC investors are paid their par value of \$30 in cash, rather than receive shares, and suffer no loss on their initial investment. The bank's total capital of \$65 is now in the form of shareholders' equity, with the initial shareholders' claim of \$70 reduced to $S_t \times (n_0 + n_1) - B = \$1.76 \times 37 - \$30 = \$35$. Hence, they bear all of the loss in bank capital.

The above calculations presume that after conversion was triggered, the bank's market value of capital equalled the trigger level of \$65. But what if the triggering event coincided with a sudden, severe plunge in the bank's asset value, as might occur during a

financial crisis? If, instead, capital crashed from somewhere above the \$65 trigger to significantly below it, say $A_t - D_t = \$50$, would the initial shareholders' still choose to exercise their option to repurchase the shares issued to COERC investors? They will as long as the value of the new shares $\alpha \times (A_t - D_t) = (30/37) \times \$50 = \$40.54$ is above the COERC par value of $B = \$30$. Thus, only if capital plunged below $B/\alpha = \$37$ so that the fully-diluted stock price is below the conversion price would COERC investors not be repaid at par and suffer losses.

However, even in this very severe case, the COERC would act as a standard CoCo and help re-capitalize the bank by converting debt to new equity. Of course, it also may be possible that capital could suddenly decline even more severely into negative territory where $A_t - D_t < 0$ and both COERC investors and shareholders would be wiped out, likely requiring regulatory authorities to resolve the failed bank. No capital instruments, short of ones with unlimited liability, could protect against such catastrophic failure. In summary, if t_r is the rights issue date when initial shareholders must decide whether to exercise their option, the payoff to COERC investors can be written as

$$V_{t_r} = \begin{cases} B & \text{if } B \leq \alpha (A_{t_r} - D_{t_r}) \\ \alpha (A_{t_r} - D_{t_r}) & \text{if } 0 < \alpha (A_{t_r} - D_{t_r}) < B \\ 0 & \text{if } A_{t_r} - D_{t_r} \leq 0 \end{cases} \quad (1)$$

We now present a structural model of the bank that examines how the likelihood of these different payoffs, along with the triggering event, affects the risk borne by COERC investors. The model allows us to compare how different parameters of the COERC contract affect its risk, and also permits us to compare COERC's risk to that of other capital instruments. It will also provide insights on how these different capital instruments might influence the risk-taking incentives of the bank's shareholders. Finally, it allows us to study how robust these capital instruments are to deviations of market prices from fundamentals.

3. Valuation Technique

Our analysis focuses on the credit risks of COERCs and other capital instruments in a setting that allows for the possibility of sudden declines in bank asset values, as typically occurs during a financial crisis. Since bank capital is potentially most valuable in minimizing financial distress during a crisis, it is important to consider how the possibility of such events affects the relative risks of proposed capital instruments.

We employ a modified version of the credit risk model of Pennacchi (2011) which is especially suited for capturing potentially severe asset value declines. Specifically, it assumes that bank asset values follow a mixed jump-diffusion process and solves for deposit and capital instrument credit spreads in an environment where all bank debt is default risky. Incorporating jumps is critical to deriving different credit spreads for different types of capital. In most models, including ours, if asset values follow simply a standard diffusion process and convert to par then capital hits the triggering threshold, then all floating-rate debt would have zero credit spreads since investors would always receive their par value. Thus, if one wishes to generate positive credit spreads that differ across COERCs, standard CoCos, and non-convertible subordinated debt, permitting sudden declines in bank asset value is essential.

3.1 *Basic Model Assumptions*

Initially, our model follows standard structural credit risk models, such as Merton (1974), by assuming a Modigliani-Miller setting where the market value of a bank's total liabilities equals the market value of its underlying assets. Later, we loosen this assumption to allow the market prices of bank shareholders' equity and capital instruments to depart from the underlying asset "fundamentals." Such a departure allows us to study the robustness of different capital instruments to manipulation or panic that could change the conversion triggering date from that based purely on fundamentals.

The model assumes that a bank issues short-maturity deposits (senior debt), shareholders' equity, and longer-maturity bonds in the form of COERCs, standard CoCos, or non-convertible subordinated debt. The funds raised by these liabilities are invested in assets

whose date t value is denoted A_t . The change in the bank's assets equals the asset's return plus changes due to the bank's cash inflows less cash outflows. Using the superscript $*$ to distinguish asset changes solely due to their rate of return, these assets' risk-neutral rate of return, dA_t^* / A_t^* , satisfies the jump – diffusion process:⁶

$$\frac{dA_t^*}{A_t^*} = (r_t - \lambda k) dt + \sigma dz + (Y_{q_t} - 1) dq_t \quad (2)$$

where dz is a Brownian motion, q_t is a Poisson counting process that increases by 1 with probability λdt ,

$$\ln(Y_{q_t}) \sim N(\mu_y, \sigma_y^2) \quad (3)$$

and $k \equiv E^Q[Y_{q_t} - 1] = \exp[\mu_y + \frac{1}{2}\sigma_y^2] - 1$ is the risk-neutral expected value of a jump. In equation (2), σ is the standard deviation of the continuous diffusion movements in the bank's assets while the parameter λ measures the probability of a jump in the assets' value. Equation (3) specifies that the jump size is lognormally distributed, where the parameter μ_y controls the mean jump size and σ_y is the jump size's standard deviation.

Because interest rates change in an uncertain manner, especially during a financial crisis, we permit the short-term default-free interest rate (e.g., Treasury bill rate), r_t , to be stochastic. Its risk-neutral process is that of the well-known Cox, Ingersoll, and Ross (1985) model:

$$dr_t = \kappa(\bar{r} - r_t) dt + \sigma_r \sqrt{r_t} dz_r \quad (4)$$

where $dz dz_r = \rho dt$.

Our model assumes bank deposits have a very short (instantaneous) maturity, but are default-risky and pay a fair, competitive interest rate. This assumption fits many large “money-center” banks which tend to rely on short-term, wholesale sources of funds, such

⁶ Modeling the “risk-neutral” or “Q-measure” processes for the bank's assets allows us to value the bank's liabilities in a general way that accounts for the assets' risks. The risk-neutral expectations operator is denoted $E^Q[\cdot]$.

as large-denomination deposits paying LIBOR. Assuming deposits have a short maturity also simplifies our analysis because the conversion of CoCos or COERCs does not affect the current value or yield on deposits. Conversion does not change the total amount of claims that are junior to deposits. It only changes the composition.⁷

Thus, let D_t be the date t quantity of bank deposits which are assumed to have an instantaneous (e.g., overnight) maturity and to pay an interest rate of $r_t + h_t$, where h_t is the deposits' fair credit spread. Another assumption of the model is that the bank attempts to target a capital ratio or asset-to-deposit ratio, so that its leverage tends to be mean-reverting. Much empirical evidence, including Flannery and Rangan (2008), Adrian and Shin (2010), and Memmel and Raupach (2010), finds that deposit growth expands (*contracts*) when banks have an excess (*a shortage*) of capital.⁸ Defining $x_t \equiv A_t/D_t$, as the date t asset-to-deposit ratio, it is assumed that the bank targets this ratio by adjusting deposit growth according to:

$$\frac{dD_t}{D_t} = g(x_t - \hat{x})dt \quad (4)$$

where the positive constant g measures the strength of mean-reversion and $\hat{x} > 1$ is the bank's target asset-to-deposit ratio.

The bank is assumed to fail (be closed by regulators) when assets fall to, or below, the par value of deposits (plus any non-convertible bonds). If failure occurs, total losses to depositors are $D_t - A_t$. While deposits are default-risky, prior to failure their value always equals their par value D_t since their short maturity allows their credit spread h_t to continually adjust to its fair value. This assumption simplifies the valuation of the bank's other liabilities since they always sum to total capital worth $A_t - D_t$. Moreover, the Appendix shows that this fair credit spread equals

⁷ Because conversion can change the bank's cash outflows due to a reduction in coupon payments, it will, in general, change future interest rates on deposits. The model accounts for this fact.

⁸ Another structural model of a firm with mean-reverting leverage is Collin-Dufresne and Goldstein (2001). They show that allowing leverage to mean-revert is necessary for matching the term structure of credit spreads of corporate bonds. Given the empirical evidence in Adrian and Shin (2010) that bank leverage displays even stronger mean-reversion than that of non-financial corporations, modeling this phenomenon appears particularly important for accurately valuing bank bonds.

$$h_t = \lambda \left[N(-d_1) - x_t \exp\left(\mu_y + \frac{1}{2}\sigma_y^2\right) N(-d_2) \right] \quad (5)$$

where $d_1 = [\ln(x_t) + \mu_y] / \sigma_y$ and $d_2 = d_1 + \sigma_y$.⁹ Note that h_t is a strictly decreasing, convex function of the bank's asset to deposit ratio, x_t .

In addition to deposits, at date 0 the bank issues subordinated bonds having a par value of B and a finite maturity date of $T > 0$. Prior to maturity or conversion, the bonds pay a continuous coupon per unit time, $c_t dt$. As we want to focus on credit spreads, we assume that bonds pay floating-rate coupons so that $c_t = r_t + s$ where s is a fixed spread over the short-term default-free rate.¹⁰ At date 0, the spread, s , is fixed such that the bond sells (is issued) at its par value, B . The method of solving for this equilibrium coupon spread will be discussed shortly.

We now specify how a CoCo or COERC bond's conversion would be triggered. The trigger can be most easily described as a threshold total capital-to-deposit ratio, χ :

$$\chi = \frac{\bar{A}_t - D_t}{D_t} \quad (6)$$

where, given the current level of deposits, $\bar{A}_t$ is the corresponding threshold value of assets at which conversion is triggered. Recall that for the example of Section 2, $D_0 = \$1,000$, $\bar{A}_t = \$1,065$, and $\chi = 6.5\%$. The only difference is that equation (6) allows for the realistic possibility that the quantity of deposits can change over time.

While the trigger based on asset values in equation (6) is well-defined, a bank's market value of assets is not directly observable. However, the fundamental relation that the market values of assets and liabilities must be equal implies $A_t = S_t \times n_0 + V_t + D_t$, where recall that S_t is the bank's date t stock price, n_0 is the number of shares outstanding, and V_t is the market value of the convertible bond. Note that the deposits' short maturity and

⁹ The credit spread depends only on the bank's current asset-to-deposit ratio and the parameters of the asset jump process. Only jumps that wipe out the bank's capital can impose losses on depositors.

¹⁰ Our results are qualitatively and quantitatively similar if we assume that bonds pay fixed coupons.

continuously-adjusting fair credit spread makes their market value equal their par value, D_t . Thus, the market value of assets, and hence total capital, can be observed from the sum of the market values of shareholders equity plus the convertible bond:

$A_t - D_t = S_t \times n_0 + V_t$. By observing the market values of equities plus bonds, equation (6) can be implemented so that conversion is triggered whenever¹¹

$$\frac{S_t \times n_0 + V_t}{D_t} \leq \chi \quad (7)$$

An alternative trigger might be based on the market value of equity ratio, say $S_t \times n_0 / D_t$. However, Glasserman and Nouri (2012) show that a trigger based solely on the stock price, and not the bond price, can be ill-defined in that there is no equilibrium. No equilibrium occurs when the conversion terms are advantageous to shareholders and disadvantageous to bondholders. The intuition is that if the event of conversion transfers bank capital value from bondholders to shareholders, so that conversion makes the stock more valuable, investor recognition of this value transfer maintains the stock price above the trigger, leading to no equilibrium. The trigger in (7) is immune to this problem because while the bond price falls in proportion to the rise in the stock price, so that their sum continues to reflect that bank's total capital and underlying asset value.¹² Although the current paper will assume CoCos and COERCs convert in such a way that there is not a value transfer, we maintain the total capital ratio trigger because it is more robust to different contractual features for convertible bonds.¹³ Also, since the total capital ratio can be written as $(A_t - D_t) / D_t = x_t - 1$, it allows us to view x_t as the "state" variable that triggers conversion whenever $x_t \leq 1 + \chi$.

¹¹ We are grateful to Stewart Myers for first suggesting this trigger.

¹² Glasserman and Nouri (2012) Section 4.6 give another example of a trigger based on the sum of two security prices that avoids the no equilibrium problem of a single security price trigger. More generally, they show that if trading occurs discretely, rather than continuously as in the current paper, a trigger based only on the stock price can lead to multiple equilibria. Such multiple equilibria due to discrete trading are also avoided by a total capital trigger in (7) because, once again, any value transfers between shareholders and bondholders do not affect the sum of the two securities.

¹³ As in Bond, Goldstein, and Prescott (2010), if there are government interventions at the time of conversion that change the total value of the bank's assets, no equilibrium or multiple equilibria may continue to exist. However, COERCs are specifically designed to avoid the need for government intervention.

Having specified the trigger, we need to consider the conversion terms. For standard CoCos, it is assumed that CoCo investors receive a fixed number of shares such that they would receive the par value of their bond if the bank's asset value equals the asset trigger threshold. This is the conversion method advocated by Flannery (2010), and it gives CoCo investors and initial shareholders fixed proportions of the bank's total capital. If n_1 is the number of new shares issued to CoCo investors, then it will satisfy $n_1 \times \bar{S}_t = B$ where $\bar{S}_t$ is the post-conversion stock price when the bank's capital equals the trigger threshold. Since total equity in this case equals $(n_0 + n_1) \times \bar{S}_t = n_0 \bar{S}_t + B = \bar{A}_t - D_t = \chi D_t$, we have

$$n_1 = \frac{n_0 B}{\bar{A}_t - B - D_t} = \frac{n_0 B}{\chi D_t - B} \quad (8)$$

Consistent with (8), if $\alpha = n_1/(n_0 + n_1)$ denotes the share of total bank capital that is owned by the CoCo investors at the time of conversion, then $\alpha = B / (\bar{A}_t - D_t)$ and the payoff at conversion to CoCo investors satisfies the same equation (1) that applies to COERC investors, where t_r now denotes the date that CoCos convert.

The critical difference between the COERC and this standard CoCo is that the number of shares that COERC investors are entitled to receive is assumed to be much greater than that given by equation (8). Equivalently, the share of total bank capital that COERC investors are entitled to receive is assumed to exceed $B / (\bar{A}_t - D_t)$, the amount for standard CoCo investors. For example, returning to our simple example in Section 2, the proportion of total capital for standard CoCos would be $\alpha = B / (\bar{A}_t - D_t) = 30/65 = 6/13 \approx 0.46$ while the value for COERCs was assumed to be $\alpha = 30/37 \approx 0.81$. As a result, with a higher value of α and greater potential dilution to the initial shareholders, equation (1) shows that there are more states of the world where COERC investors receive their bond's par value compared to the states where CoCo investors receive theirs. The greater potential dilution coupled with the initial shareholders' right to repurchase the COERC investors' shares at par, makes COERCs less default-risky than the standard CoCo.

Another more minor difference between CoCos and COERCs is the date at which investors receive the payoff given in equation (1). CoCos' payoff can be determined immediately when conversion is triggered, say at date t_c . However, for COERCs a rights offering must take place following this trigger date in order to give the initial shareholders the time to decide whether to repurchase the newly issued COERC shares. In practice, a rights offering would be completed at some date $t_r > t_c$ where, for example, $t_r = t_c + 20$ trading days if it takes approximately one month for a rights offering to be completed. Hence, our model assumes that the payoff obtained by CoCo investors occurs at the trigger date while the payoff to COERC investors occurs 20 trading days later.¹⁴

One additional bond that we analyze is non-convertible subordinated debt. As with CoCos and COERCs, subordinated debt investors receive a floating-rate coupon and the par value of their bond, B , at maturity as long as the bank's asset value exceeds $D_t + B$, the total par value of debt. If, prior to maturity, the bank's asset value no longer exceeds total debt, the subordinated debt holders receive a final payoff of $\max[A_t - D_t, 0]$.

The last bank liability is shareholders' equity. It is assumed to be paid a continuous dividend equal to a constant proportion of the bank's net worth, $\delta(A_t - B - D_t)dt$, where $A_t - (B + D_t)$ is the difference between the bank's asset value and the par value of its debt, and δ is approximately the dividend yield of bank equity. At the date of bond conversion or bond maturity, the value of the initial shareholders' equity equals the bank's residual capital after payoffs are made to bondholders as was specified above.

While a closed-form solution exists for the equilibrium credit spread that the bank pays on its short-term deposits (equation (5)), it is necessary to numerically calculate the equilibrium credit spread on the bank's bonds, s . Similar to Boyle (1977), we use a straightforward Monte Carlo valuation technique that simulates the risk-neutral processes

¹⁴ Since the asset value relevant for COERC investors' payoff, A_{t_r} , is for a date following the asset value triggering conversion, A_{t_c} , our model and calculations account for the possibility that COERC investors are exposed to further asset value declines during the rights offering period.

for the bank's asset-to-deposit ratio, x_t , and the instantaneous-maturity interest rate, r_t . The Appendix shows how the process for x_t is derived from the bank's asset process, A_t , where the change in the bank's assets equals the return earned on the bank's assets (equation (2)), less interest payments to depositors, coupon payments to bondholders, and dividend payments to shareholders, plus deposit changes that target capital (equation (4)). The value of bonds reflects their coupon payments prior to conversion or maturity plus their payoffs at conversion or maturity, where conversion is determined by whether the value of assets breaches the capital ratio threshold given in equation (6). This Monte Carlo valuation leads to a date 0 bond value, V_0 , for a given spread, s . Then, the bond's fair initial credit spread, s^* , is determined by varying s until $V_0 = B$; that is, until the bond initially sells for its par value.

3.2 Model Parameter Estimates

By recapitalizing banks prior to severe financial distress, thereby reducing the need for a government bailout, CoCos (and COERCs in particular) will be most valuable when issued by banks considered "too-big-to-fail." Therefore we calibrate the model's parameters using data on three large U.S. banks: Bank of America, Citigroup, and JPMorgan Chase. For each bank, we estimated a daily asset return process over the period January 2, 2003 to December 30, 2011 by calculating market returns on the bank's total liabilities, based on the assumption that the market return on the bank's total assets equals the market return of its total liabilities. From information in quarterly Federal Reserve Y9-C Reports (Consolidated Financial Statements for Bank Holding Companies), we obtained daily estimates of each bank's amounts of short-term senior debt (mainly deposits), senior bonds, subordinated bonds, and preferred stock.¹⁵ Along with the bank's daily market value of shareholders' equity obtained from the Center for Research in Security Prices (CRSP), we calculated daily proportions of the bank's liabilities in these five different liability classes. For example, the average liability proportions cross these three banks over the sample period was 71.6%, 15.5%, 2.5%,

¹⁵ To estimate daily amounts from quarterly data, a cubic spline was fit for each trading day between the quarterly observations.

0.5%, and 9.8% for short-term debt, senior bonds, subordinated bonds, preferred stock, and common shareholders' equity, respectively.

By calculating the product of a bank's daily liability proportions and the market rates of return earned by each liability class, we obtained the daily return on the bank's total liabilities. Consistent with our model, we proxied the daily return on the bank's short-term debt by the overnight LIBOR. The daily return on senior bonds was estimated from daily changes in each bank's 5-year credit default swap (CDS) spread. Subordinated bond returns were computed using daily TRACE transaction prices of a representative subordinated debt issue of each bank.¹⁶ Daily preferred stock returns were obtained from Bloomberg while daily common stock returns were obtained from CRSP.

Calculations over the nine year period led to 2,270 daily total liability returns (equal to total asset returns) for each of the three banks. We assumed that a "jump" event occurred on a given day if the return was different from the mean daily return by more than three standard deviations, an event that averaged approximately 5 times per year for each bank, providing a jump frequency estimate of $\lambda = 5$.¹⁷ The sample standard deviation of the size of these jump returns provided an estimate of $\sigma_j = 0.0125$; that is a 1.25% daily total asset change. After eliminating these jump events from the daily return series, we found that the standard deviation of the remaining "diffusion-generated" returns was approximately $\sigma = 0.03$, or an annual asset return standard deviation of 3%.

By calibrating the risk-neutral jump frequency and jump volatility parameters, λ and σ_j , from the time series of returns, we assume that they equal their physical process counterparts. Pan (2002) makes this same assumption when estimating a similar jump-diffusion process for the S&P500 index return. However, she assumes that the risk-neutral expected jump size differs from the physical (actual) expected jump size by a risk premium. In our sample, the average jump size for the three banks over the nine-year period, call it k^P , is close to zero, equal to 0.00025 (or 2.5 basis points). We follow Pan

¹⁶ The subordinated debt issues that were used are those given in Table 1.

¹⁷ In the absence of jumps where returns are generated by only a (normal) diffusion process, the expected number of returns exceeding three standard deviations would be less than one per year.

(2002) and assume that the risk premium from jumps is reflected solely in the mean jump size and set $\mu_y = -0.0025$ so that the risk-neutral expected jump size is $k = E^Q[Y_{q_r} - 1] = \exp[\mu_y + \frac{1}{2}\sigma_y^2] - 1 = -0.0024$ and the implied jump risk premium is $\lambda(k^P - k) = 1.3\%$.

This excess rate of return on bank assets is slightly greater than the 1% excess rate of return that others have estimated for a large sample of banks, but it is consistent with the evidence finding greater systematic risk for the largest of banks.¹⁸

We assume a dividend yield of $\delta = 2\%$, which is slightly lower than the average dividend yields for Bank of America, Citigroup, and JPMorgan over our sample period, but significantly higher than their current dividend yields of less than 1%. The target total capital-to-deposit ratio for banks is assumed to be 14% ($\hat{x} = 1.14$), which is approximately the sample average ratio of total capital to short-term and senior debt for these three banks. Consistent with evidence in Adrian and Shin (2010) and Memmel and Raupach (2010), we also assume a capital targeting mean reversion speed of $g = \frac{1}{2}$, so that approximately one-half of a bank's deviation of capital from its target is expected to be reduced over the next year.

The remaining parameters relate to the Cox, Ingersoll, and Ross (1985) default-free term structure. We chose parameter estimates similar to Duan and Simonato (1999) with $\kappa = 0.114$, $\bar{r} = 6.45\%$, $\sigma_r = 0.07$, and $\rho = -0.2$. Assuming an initial short-rate of $r_0 = 2\%$, these parameters lead to a five-year, fixed-coupon default-free bond having a par yield of 3%.

4. Basic Model Results

Our benchmark bonds (CoCos, COERCs, and non-convertible subordinated debt) are assumed to have a five-year maturity and an initial par value equal to 3% of deposits; that is, $B/D_0 = 3\%$. This is the assumption of our previous numerical example and is comparable to the amounts of non-common equity capital that our three sample banks

¹⁸ Pennacchi (2000) estimates a 1% excess asset return from all commercial banks listed on CRSP during 1926 to 1996. Demsetz and Strahan (1997) and De Jonghe (2010) find that the largest commercial banks have greater systematic risk, particularly if they undertake investment banking activities.

have traditionally issued.¹⁹ For CoCos and COERCs, we assume that conversion is triggered when the total capital to deposit ratio, χ , breaches the 6.5% threshold. Given an initial bond par value to deposit ratio of 3%, this total capital threshold implies a common equity trigger level of approximately 3.5%. As in the previous example, we assume that the share of total bank capital that COERC investors are entitled to receive when conversion is triggered equals $\alpha = 30/37$.

Figure 2 plots the new issue credit spreads for COERCs, CoCos, and non-convertible subordinated debt based on the previous section's valuation method and parameter values. The horizontal axis gives the percent of total bank capital per deposits, $(A_0 - D_0)/D_0$, at the time of the bonds are issued. The vertical axis is the new issue credit spreads, s , in basis points. As would be expected, as a bank's initial total capital declines, all three bonds' new issue credit spreads rise. For the case of non-convertible subordinated debt, lower initial bank capital increases the likelihood that the bonds' investors would suffer losses if the bank failed. That would occur if, over the bond's five-year life, there was a sudden decline in capital strictly below the bond's par value, equal initially to 3% of deposits. For the case of CoCos, lower initial bank capital increases the likelihood of a conversion where CoCo investors could suffer losses. Losses would occur if, over the bond's five year life, there was a sudden decline in capital strictly below the $\chi = 6.5\%$ capital to deposit threshold. Only if there is a gradual (continuous) decline in capital that led to conversion exactly at the 6.5% capital ratio trigger would CoCo investors receive shares that are worth their bond's par value and, thereby, avoid a loss.

Similar to CoCos, COERCs could also sustain losses at conversion, and the likelihood of such losses is greater when the bank's initial capital is less. However, COERC losses require a much greater decline in bank capital around the time of conversion. As discussed earlier, when $\alpha = 30/37$ the capital/deposit ratio would need to fall from the 6.5% trigger to below 3.7% before the bank's shareholders would lack the incentive to

¹⁹ From 2003 to 2011, the average ratio of subordinated debt plus preferred stock to short-term and senior debt was 4.1%, 2.7%, and 3.4% for Bank of America, Citigroup, and JPMorgan Chase, respectively.

repurchase the shares issued to COERC investors at the bond's \$30 par value.²⁰ Because the likelihood of this event is relatively small, COERC investors are better protected from losses compared to investors in CoCos and subordinated debt. Thus, for any level of initial bank capital, COERC credit spreads are significantly lower than those for the other two bonds.²¹

It should be emphasized that if bank assets followed a pure Brownian motion diffusion process, so that $\lambda = 0$ and/or $\sigma_y = \mu_y = 0$, the bank's asset value would have a continuous sample path and the credit spreads for the three bonds in Figure 2 would equal zero for every initial level of capital.²² For the case of subordinated debt, regulators could always close the bank at the point that assets exactly equal the par value of total debt, $D_t + B$, allowing full recovery by debt holders. Also, CoCos and COERCs would always convert when the bank's capital value exactly equals the trigger level, also ensuring that investors receive the par value of their bonds. Thus, the realistic possibility of sudden asset value losses is what generates differences in the three bonds' credit spreads.

To illustrate how the threat of dilution protects COERC investors, Figure 3 reports new issue credit spreads for COERCs that differ by the number of shares that investors are entitled to receive at conversion. Specifically we consider $n_1 = 40, 30, 20$, or 10 shares, so that the dilution ratio is $\alpha = 40/47, 30/37, 20/27$, or $10/17$. Clearly, for a given level of initial bank capital, new issue credit spreads are lower when COERC investors are entitled to greater proportion of the bank's capital. The intuition is the same as discussed earlier. COERC investors would be subject to losses only when there is a sudden decline from the 6.5% capital ratio trigger to a capital ratio below $(B/\alpha)/1000$, which are capital/deposit ratios of 3.53%, 3.70%, 4.05%, and 5.10%, respectively.

²⁰ Recall from the COERC payoff in equation (1), capital below 3.7% implies a payoff indicated by the right-hand side's second or third lines, rather than the first which returns the bond's par value.

²¹ Given the same conversion threshold, χ , COERC credit spreads are lower than comparable CoCo credit spreads as long as the share of capital that COERC investors are entitled to receive, α , exceeds that for CoCo investors. However, COERC (and CoCo) credit spreads will not, in general, be less than subordinated debt credit spreads. As will be illustrated next, reducing the dilution ratio, α , and the conversion threshold, χ , can raise COERC credit spreads above those of subordinated debt.

²² Moreover, as can be seen from equation (5), credit spreads on deposits, h_t , would also equal zero. An example where asset returns follow a pure diffusion process is Albul, Jaffee and Tchisty (2010), and CoCos in their model have zero credit spreads (are default-free).

Another contract feature that affects the risk of COERCs (as well as CoCos) is the trigger level of capital. As was just mentioned, when $\alpha = 30/37$ capital would need to fall suddenly from the trigger level to below 3.70% in order for COERC investors to suffer a loss. The likelihood of this happening is less the higher is the trigger capital ratio. Previous graphs assumed a trigger capital/deposit threshold of $\chi = 6.5\%$. Figure 4 graphs new issue credit spreads for COERCs where the trigger capital ratio threshold equals either $\chi = 5\%$, 5.5% , 6.0% , or 6.5% . Clearly for any level of initial bank capital, new issue COERC credit spreads are lower when the trigger threshold, χ , is higher. While conversion is less likely the lower is the trigger threshold, if conversion does occur at the lower threshold COERC investors are more likely to sustain losses. For example, starting from a capital value just above the thresholds, when $\chi = 5.0\%$ an asset value decline of just over 1.3% ($5.0\% - 3.7\%$) would lead to COERC investor losses, whereas when $\chi = 6.5\%$ an asset value decline of just over 2.8% ($6.5\% - 3.7\%$) would be required for COERC investor losses.

The design features that reduce the default risk of COERCs have implications for a bank's risk-shifting incentives. Merton (1974) noted that the shareholders' equity of a levered, limited-liability firm is comparable to a call option written on the firm's assets with a strike price equal to the promised payment on the firm's debt. By raising the risk of the firm's assets, shareholders can increase the volatility and, in turn, the value of their call option at the expense of the firm's debt value. This moral hazard incentive to transfer value from debt holders to equity holders tends to rise as the firm becomes more levered.

The risk-shifting incentives of banks that issue COERCs, CoCos, and non-convertible subordinated debt can be compared in the context of our model. We calculate the change in the value of a bank's shareholders' equity following a rise in the volatility of jump risk, $\partial E / \partial \sigma_j$. Note that this comparative static exercise does not change the bank's asset value, though from equation (5) it does raise the credit spread on short-term deposits, with the effect that the deposits' market value continues to equal their par value. Consequently, the rise in jump risk transfers value to the bank's shareholders at the expense of its

bondholders; that is, $\partial E/\partial \sigma_y = -\partial V/\partial \sigma_y$. Figure 5 reports numerical estimates of the derivative $\partial E/\partial \sigma_y$ for a bank that issues subordinated debt, CoCos, or COERCs.²³ The calculation is made for current bank capital levels ranging from 7% to 20% of deposits. The benchmark parameters and contract features are assumed for CoCos and COERCs ($\chi = 6.5\%$, $\alpha=30/37$).

Figure 5 shows that for any level of capital, $\partial E/\partial \sigma_y$ is lowest when the bank issues COERCs, second lowest for CoCos, and highest for subordinated debt. The degree of moral hazard tends to be greater as the bank's capital declines, except for convertible bonds at capital levels near the conversion threshold.²⁴ However, the most important finding is that a bank that issues COERCs has a smaller incentive to engage in activities or make investments that would increase the volatility of jumps. The relatively high number of shares that COERC investors are entitled to receive at conversion better protects the par value of their investment compared to investors in CoCos. Furthermore, because COERCs have a high probability of being converted at par, they benefit from the ability to exit the bank earlier than non-convertible bond investors.

While not reported here, the same qualitative findings occur if one considers the derivative $\partial E/\partial \lambda$, which captures a bank's moral hazard incentive to choose investments that would increase the frequency of jumps. When a bank issues COERCs, it has the least incentive to raise jump frequency, followed by when it issues CoCos, then when it issues subordinated debt. The same ordering occurs if one considers a bank's moral hazard

²³ The bank is assumed to have issued each bond at its fair credit spread when the bank's total capital equaled 10% of deposits. For each bond, the derivative is calculated numerically by the discrete approximation $\Delta E/\Delta \sigma_y$ where $\Delta \sigma_y = (0.0150 - 0.0125) = 0.0025$. In other words, for each current level of bank capital, we valued bank equity by 200,000 Monte Carlo simulations when $\sigma_y = 0.0125$ (the benchmark case) and then repeated the equity valuation but with $\sigma_y = 0.0150$.

²⁴ For convertible bonds near the conversion threshold, it can be relatively more likely that the threshold will be hit exactly (due to diffusion movements in asset values) which would result in repayment at par. Furthermore, at low levels of capital, the market value of equity is also low, so that its absolute increase from greater risk will tend not to be as great, though it may be greater as a proportion of equity.

incentive to reduce the mean jump size, μ_y . A COERC's greater protection against jump risk reduces moral hazard.²⁵

Subordinated debt, CoCos, and COERCs also affect another bank incentive, namely, "debt overhang." In general, when a bank's debt is subject to possible default losses, issuing new equity will make these losses less likely and increase the debt's value. Given that investors pay a fair price for the new equity issue, the increase in the debt's value must come at the expense of the bank's initial shareholders' equity. Such a loss in shareholder value creates a disincentive for the bank to replenish its equity following a decline in the bank's capital, which is the Myers (1977) debt overhang problem.

We quantify debt overhang by calculating the change in the value of the bank's shareholders' equity, ∂E , following a new equity issue that increases the bank's assets by ∂A . Since new equity is assumed to be fairly priced, the change in the value of the pre-existing shareholders' equity is $\partial E/\partial A - 1$. A negative value for this quantity indicates debt overhang. Similar to previous figures that analyzed risk-shifting incentives, Figure 6 shows calculations of $\partial E/\partial A - 1$ for a bank that issued either subordinated debt, CoCos, or a COERC. As was done in the comparison of risk-shifting, the benchmark parameters and contract features are assumed for CoCos and COERCs.²⁶

Relative to non-convertible subordinated debt, Figure 6 shows that COERCs reduce the debt overhang problem for any level of bank capital from 7% to 14% of deposits. In addition, for most capital levels the debt overhang problem also is smaller for a bank that issues COERCs relative to one that issues CoCos. The only exception occurs at low

²⁵ Unreported calculations also show that a bank's incentive to raise assets' diffusion volatility, $\partial E/\partial \sigma$, is also smaller for COERCs, except when bank capital becomes very low. With low capital, a rise in (continuous) Brownian motion risk makes it more likely that, in the case of CoCos, assets will exactly equal the trigger threshold at conversion or, in the case of subordinated debt, assets will exactly equal total debt at the time the bank is closed. In such scenarios, CoCo and subordinated debt investors suffer no losses. This is in contrast to higher jump risk that makes it more likely that conversions and bank closures occur following downward jumps where these investors would suffer losses.

²⁶ The bank is assumed to have issued each bond at its fair credit spread when the bank's total capital equaled 10% of deposits. For each bond, the derivative $\partial E/\partial A$ is calculated numerically by the discrete approximation $\Delta E/\Delta A$ where $\Delta A = 0.125\%$ of deposits. The different values of equity for each asset (capital) level were calculated by 1 million Monte Carlo simulations.

capital levels where the two bonds are close to their conversion thresholds. There we see that $\partial E/\partial A - 1$ actually turns positive. The intuition for this result is that conversion due to a diffusion movement in asset value becomes more likely when capital is close to the threshold, an event that would pay the bondholders' their par values and which the shareholders would wish to avoid. However, taken as a whole, our analysis indicates that COERCs mitigate debt overhang and could improve financial stability by removing much of the bank's disincentive to replenish capital following an expected loss.

5. Extending the Model to Incorporate Deviations from Fundamentals

CoCos with market value triggers have been criticized because market prices of bank stocks and CoCos, on which triggers would be based, may not always reflect the underlying fundamental asset value of the bank. Deviations of market prices from fundamentals could harm the bank's shareholders if premature conversions provide CoCo investors with undervalued shares that heavily dilute the initial shareholders. Indeed, when a bank issues CoCos, speculators have the incentive to buy them and then short-sell the bank's stock in order to force an economically "unjustified" conversion that benefits CoCo investors at the expense of the diluted initial shareholders. Even without short-sellers, bank shareholders may be concerned that an irrational market panic or a "death spiral" could lead to unjustified conversions and dilutions of their ownership stake.²⁷ A related concern for shareholders may be a loss of control if CoCo investors end up with a significant share of the bank's equity after conversion.

To illustrate how CoCos have the potential to harm the bank's initial shareholders, recall the earlier simple example where a bank has issued \$1,000 in deposits, CoCos with a par value of \$30, and 7 shares of stock, currently valued at \$10 per share, so that the bank's total capital is \$100. If capital falls to \$65, CoCo investors are issued 6 new shares. Now suppose that a speculator purchases the CoCos for \$30 and, via short-selling or an unjustified rumour that generates a panic, is able to manipulate the bank's stock price down to \$5. Conversion is then triggered because the market value of capital equals \$65,

²⁷ Calomiris and Herring (2011) propose to outlaw short-selling of bank stocks to prevent death spirals.

the sum of the \$30 CoCos plus the $7 \times \$5 = \$35$ value of equity. Thus CoCo investors receive 6 new shares. After the short-selling ends or the panic subsides, suppose that the bank's total capital is now recognized to still equal its fundamental value of \$100. Then the price per share would equal $\$100/13 = \$7.69$, giving the CoCo investors a claim worth $6 \times \$7.69 = \$46.15$ and the initial shareholders a claim worth $7 \times \$7.69 = \$53.85$. As a result, manipulation or panic that led to a temporary reduction in market prices below fundamentals transfers $\$70 - \$53.85 = \$16.15$ from shareholders to CoCo investors.

This section extends the basic model of Section 3 to formally consider how deviations from market price fundamentals, as might result from manipulation or panics, affects the values of CoCos and COERCs relative to the bank's initial shareholders' equity. We continue to assume that the "true" or "fundamental" value of the bank's assets equals A_t and follows the same risk-neutral rate of return process assumed earlier, equation (2). However, the market value of capital no longer is assumed to satisfy the fundamental value relation $S_t \times n_0 + V_t = A_t - D_t$. Instead, we now assume the market value of the bank's total liabilities differs from the fundamental value of its assets:

$$S_t \times n_0 + V_t + D_t = A_t e^{\eta_t} \quad (9)$$

where η_t is a "noise" term which represents a deviation of the market value of liabilities from the fundamental value of assets, A_t . When η_t is positive (*negative*), the bank's liabilities are over- (*under-*) valued relative to the bank's fundamental asset value.

It is most natural to think that η_t is non-zero because it is mainly the bank's stock price, S_t , that does not fully reflect the bank's fundamental underlying assets, A_t . The fundamental value of bank assets is unlikely to be directly observable by outside investors since at least some of the bank's assets (e.g., most loans) are not traded or investors may not know exactly which types of assets the bank currently holds. Moreover, manipulation by better-informed speculators could force stock prices from fundamental values due to limited arbitrage by lesser-informed investors. Overly optimistic or pessimistic beliefs regarding the banks' prospects, as might characterize "bubbles" or "panics," could lead to non-fundamental stock (and perhaps bond) prices.

As do Jurek and Yang (2007), we assume that the deviation from fundamentals, which we simply call “noise,” follows the mean-reverting Ornstein-Uhlenbeck process

$$d\eta_t = -\kappa_\eta \eta_t dt + \sigma_\eta dz_\eta \quad (10)$$

where $\kappa_\eta > 0$ measures the speed at which noise is expected to revert to its unconditional mean of zero, and σ_η is the volatility of changes in the level of noise.

As before, conversion is assumed to occur then equation (7) holds, but the market value of capital, $S_t \times n_0 + V_t$, now is assumed to equal $A_t e^{\eta_t} - D_t$, rather than the fundamental value of capital, $A_t - D_t$. However, for standard CoCos, we assume that after conversion the noise, η_t , returns to zero, so that the payoff to CoCo investors after conversion is given by $\max [\alpha(A_t - D_t), 0]$, where, for example, $\alpha = 6/13$ for standard CoCos. For COERCs, we assume that during the rights offering period, shareholders make their decision whether to repurchase shares based on capital observed with noise, $A_t e^{\eta_t} - D_t$, but following that decision COERCs are again valued based on the fundamental payoff (1). Thus, the payoff to COERCs is now

$$V_{t_r} = \begin{cases} B & \text{if } B \leq \alpha(A_{t_r} e^{\eta_{t_r}} - D_{t_r}) \\ \alpha(A_{t_r} - D_{t_r}) & \text{if } 0 < \alpha(A_{t_r} e^{\eta_{t_r}} - D_{t_r}) < B \\ 0 & \text{if } A_{t_r} - D_{t_r} \leq 0 \end{cases} \quad (11)$$

where, for example, $\alpha = 30/37$.

Our analysis incorporating noise maintains all of the parameter and contract assumptions made earlier except that we also need estimates for κ_η and σ_η of the mean-reverting noise process in (10). One gauge of size and persistence of stock price deviations from fundamentals comes from “Siamese Twins,” which are firms that have two classes of shares with each share class owning a fixed proportion of dividends and assets of the firm. As pointed out by Rosenthal and Young (1990), the prices of these two share classes should always trade at a fixed ratio, equal to the ratio of their cash flow rights.

However, empirical evidence from two firms with such dual share classes, Royal Dutch/Shell and Unilever NV/Unilever PLC, finds that the ratio of dual share prices persistently deviates from the fixed ratio of their fundamental cash flow rights.

Jurek and Yang (2007) use daily stock price data of Royal Dutch/Shell and Unilever NV/PLC from 1970 to 2006 to estimate the non-fundamental noise process for η_t in (10). For these two firms' dual class stocks, they estimate an average annualized value of $\sigma_\eta = 6.4\%$ and $\kappa_\eta = 3.56\%$, the latter estimate implying a mean reversion half-life of 49 trading days. We use their estimates assuming that bank total capital has the same deviations from fundamentals as these firms' stocks. However, since we model deviations at the asset level, we adjust for an average bank capital/asset ratio of roughly 14%, so that our estimate of σ_η is $0.14 \times 6.4\% = 0.896\%$; that is, the observed bank assets deviate from their fundamental value with an annual standard deviation of slightly less than 1%. This noise standard deviation equals about one-quarter of our model's fundamental bank asset return standard deviation, which is slightly less than 4%.²⁸

As detailed in the Appendix, with the addition of this noise affecting the bank's observed asset value and capital, $S_t \times n_0 + V_t = A_t e^{\eta_t} - D_t$, the previously described risk-neutral valuation method is used to solve for the fair new issue credit spreads for CoCos and COERCs. Figure 7 graphs these fair credit spreads for CoCos and COERCs when banks have starting capital from 9% to 20% and when the fundamental value of assets is observed both without and with noise.²⁹ As seen in the figure, noise has a much greater impact on the value of CoCos. For example, if a bank issued CoCos when its total capital/deposits was 9%, the fair credit spread without noise would be 243 basis points but only 202 basis points if total capital was observed with noise, a difference of 41bp. In contrast, if the same bank had issued COERCs, the fair credit spreads without and with noise would be 38 and 36 basis points, respectively, a difference of only 2 basis points.³⁰

²⁸ As discussed earlier, a 3.96% fundamental asset return standard deviation was the average calibrated from Bank of America, Citigroup, and JPMorgan Chase, and includes both diffusion and jump risks.

²⁹ Our fair value calculations with noise assume that at the initial date 0, $\eta_0 = 0$. The calculations without noise are the same as those in Figure 1.

³⁰ For better visual clarity, Figure 7 graphs credit spreads starting with a bank capital/deposit ratio of 9%. However, the same qualitative differences occur when the bank's initial capital is as low as 7%: the CoCo

The intuition for these results should be clear from the contractual payoffs of CoCos and COERCs. When $\eta_t > 0$ so that the market values bank capital above its fundamentals (as might be the case in a “bubble” period), conversion may be delayed relative to fundamentals if $(S_t \times n_0 + V_t)/D_t = (A_t e^{\eta_t} - D_t)/D_t > \chi > (A_t - D_t)/D_t$. This situation does not transfer much value between bond investors and initial shareholders since the unconverted bonds continue to receive their coupon payments.³¹ However, an equally likely case is $\eta_t < 0$ where the market values bank capital below its fundamentals, a situation that might be due to manipulative short-selling or an unjustified panic. Here if $(S_t \times n_0 + V_t)/D_t = (A_t e^{\eta_t} - D_t)/D_t < \chi < (A_t - D_t)/D_t$, conversion gives CoCo investors a share of fundamental bank capital that exceeds their bond’s par value.³² As illustrated in the simple numerical example at the beginning of this section, CoCo investors benefit at the expense of the initial shareholders. Consequently, for a given coupon spread, CoCos would be worth more, and initial shareholders’ equity would be worth less, in the presence of noise. That explains why if this ex-post transfer of value is recognized initially, the fair credit spread of CoCos is significantly lower in the presence of noise.

In contrast, in the same situation of manipulation or panic where $\eta_t < 0$ and $(S_t \times n_0 + V_t)/D_t = (A_t e^{\eta_t} - D_t)/D_t < \chi < (A_t - D_t)/D_t$, the triggering of conversion is unlikely to transfer value from initial shareholders to COERC investors. If initial shareholders repurchase the new shares that COERC investors are entitled to receive whenever the shares’ observed market value exceeds the bonds’ par value, $B < \alpha(A_t e^{\eta_t} - D_t)$, that event would most likely continue to occur. Only if $\alpha(A_t e^{\eta_t} - D_t) < B < \alpha\chi D_t < \alpha(A_t - D_t)$ would there be a transfer from shareholders to COERC investors, which is unlikely because, as discussed

credit spreads without and with noise are 788bp versus 705bp, a difference of 83bp. The COERC credit spreads without and with noise are 120bp and 121bp, a difference of less than 1 bp.

³¹ Delayed conversion may have some harm to bondholders, but the effect is relatively small. If conversion is delayed but eventually does occur despite $\eta_t > 0$, convertible bonds are more likely to suffer a loss of par value. This case is similar to that with no noise but a lower conversion threshold, χ , as was illustrated in Figure 3. With a smaller fundamental value of capital, a jump below the threshold makes it less likely that bondholders would receive their par values following conversion.

³² Since from (8) CoCo investors’ share of capital equals $\alpha = B/(\chi D_t)$, then $B = \alpha\chi D_t < \alpha(A_t - D_t)$.

in Section 2, α is set to be significantly greater than $B/(\chi D_t)$ which is the proportion of shares given to CoCo investors. The non-fundamental information at the end of the rights offering period, η_t , would need to be very negative to persuade shareholders to not exercise their repurchase option.

Because an ex-post transfer from shareholders to COERC investors is much less likely, the values of COERCs and shareholders' equity is much less sensitive to noise due to manipulation or panic. Recognizing this fact, speculators will have little incentive to short sell the bank's stock in order to prematurely trigger conversion. While we have modelled noise as an exogenous process, a more general model with incentive-based manipulation suggests that manipulation will be less, and bank stock prices will be more transparent, when they issue COERCs rather than CoCos.³³

6. Further Considerations

The COERC's trigger in (7) is specified as a threshold level for the market value of total capital; that is, the sum of the market values of COERCs and equity. As detailed in Glasserman and Nouri (2012), the main reason for choosing this trigger, rather than one based solely on the bank's stock price, is to avoid an ill-defined trigger that would produce no equilibrium. Of course, the viability of such a trigger will depend on the availability of information on senior debt and the market prices of COERCs. Large U.S. banks must already report their senior debt to the Federal Reserve on a weekly basis.³⁴ Whether COERCs will be sufficiently liquid to observe their market prices on a frequent basis cannot be known with certainty before they exist. However, while many corporate bonds are not very liquid, subordinated debt issued by large banks is.

³³ The design of the contract also discourages manipulation by the bank's other bondholders. Bolton and Samama (2010) argue that other bondholders may want to short the bank's stock to trigger conversion and improve their seniority. However, because COERC investors are repaid in these circumstances, such activity would not improve other bondholders' seniority.

³⁴ Banks report the amounts of their deposits and other non-capital liabilities in form FR 2644 Weekly Report of Selected Assets and Liabilities of Domestically Chartered Commercial Banks and U.S. Branches and Agencies of Foreign Banks.

To investigate the liquidity of large banks' subordinated debt (for which COERCs will be a special case), we collected TRACE transactions from January 2007 to December 2011 for three different subordinated notes issued by Bank of America, Citigroup, and JPMorgan Chase. Summary statistics in Table 1 show that the average daily trades in these three bonds exceeded 32. Moreover, trading increased during 2008 and 2009 at the height of the crisis, so it was not the case that liquidity dried up during the crisis. For these three bonds, there were 20 instances when one of the bonds did not trade on a given day. However, five of these cases were on a November 11, which is the Veterans Day holiday when bond markets were open but overall trading is expected to be light. If we excluded these instances, there would be only 15 bond-days with zero trades, or an average of only one day per year with no trading.

Moreover, a bond's liquidity tends to be greater the lower is its credit risk (Bühler and Trapp (2009)), and, as we have shown above (Figure 2), COERCs should have lower risk than standard subordinated debt. The relatively low risk of COERCs has another advantage relative to standard CoCos. Standard CoCos are often criticized for being hard to value, which makes them unattractive to traditional fixed-income investors and makes credit rating agencies reluctant to rate them. Investors may shy away from them because they do not wish to become bank shareholders, especially when the bank is in financial distress. This criticism applies most to CoCos with triggers based on regulatory capital ratios and/or regulator discretion: banks can manipulate regulatory accounting and regulators' decisions are subject to political pressure.³⁵ Even if the timing of conversion is hard to predict, the fact that COERC investors almost always receive their bonds' par value in cash should qualify them for a very high quality credit rating.

³⁵ For example, Credit Suisse's CoCo, issued in February 2011, converts to equity if the bank's core Tier1 capital ratio falls below 7%. However, the Swiss regulator, FINMA, can also force conversion if it sees that Credit Suisse needs public funds to avoid insolvency. The conversion price is the minimum of \$20 and the volume weighted average stock price five days before the conversion notice. Arguably, there are three reasons why this CoCo is risky. First the trigger is based on regulatory accounting capital ratios so that the stock price at the time of conversion is unpredictable. Second, if the stock price at the time of conversion is less than \$20, CoCo investors can incur a significant loss. Third, the ability of FINMA to force conversion before the trigger is reached creates additional risk that is difficult to price.

The COERC's design also should qualify it for favourable U.S. tax treatment. Under current U.S. tax law, the deductibility of interest on standard CoCos is in question.³⁶ The reason is that the U.S. Internal Revenue Service may not treat a CoCo bond as debt for tax purposes when there is a "high" likelihood that it will be converted to equity (IRS Code Section 163). However, since COERC investors are almost always repaid in cash, and are only repaid in equity at a loss, a strong argument can be made that their tax treatment should be the same as standard bonds.

As we have shown above, the COERC reduces the costs resulting from conflicts between bondholders and shareholders (Jensen and Meckling (1976) and Myers (1977)), and as such, should not only be of interest to banks but also to corporations in general. These costs of financial distress occur because shareholders have limited liability: they only focus on upside gains while debt holders are only concerned with downside losses. The COERC eliminates this limited liability to a large extent by forcing shareholders to repay debt in order to avoid heavy dilution. Although, ex-post, shareholders may dislike being pressured to repay debt, the ex-ante benefit is that they can borrow at close the rate paid by the government, an institution that can also coerce equityholders (i.e., taxpayers) to bail out debt holders.³⁷

In general, shareholders may be reluctant to authorise a large issue of new shares, as would be required under a COERC. Such reluctance may be driven by the fear of losing control to new shareholders. However, since the COERC structure allows existing shareholders to preserve their pre-emptive rights (again a unique feature relative to other CoCos), control by the initial shareholders' can be maintained. Moreover, existing shareholders should not fear being liquidity constrained when COERCs convert since they can sell their repurchase rights to non-constrained investors. In many countries brokers automatically sell unexercised rights if investors fail to inform them of a decision whether to exercise. Such a procedure guarantees the success of the rights issue provided,

³⁶ In Europe, interest on CoCos is tax deductible, which may explain why only European banks have issued CoCos thus far.

³⁷ Government coercion is possible as long as the tax base is large enough to repay the debt. The 2011 sovereign debt crisis revealed limitations to governments' ability to raise taxes.

of course, the rights are in the money. While in some cases an equity issue can be interpreted as a negative signal (Myers and Majluf (1984)), a rights issue to repay COERCs should not since the corporation is not issuing shares because it believes the stock is overvalued. The rights issue is an automatic consequence of the market of capital breaching its trigger, not a timing decision by the management.

One potential concern about CoCos in general is the effect on fully diluted earnings per share (EPS).³⁸ Although diluted EPS may not be economically meaningful, in practice many investors focus on this financial ratio. According to US GAAP “Potentially issuable shares are included in diluted EPS using the ‘if-converted’ method if one or more contingencies relate to the entity’s share price.” As the COERC trigger is based on a market capital ratio, not a stock price, it is unclear whether a firm issuing a COERC would have to report a heavily reduced EPS, particularly since shareholders have purchase rights. Under IFRS “potentially issuable shares are considered ‘contingently issuable’ and are included in diluted EPS using the if-converted method only if the contingencies are satisfied at the end of the reporting period.” This rule would appear to lead to dilution only if conversion is triggered, which of course makes sense.

Kashyap, Rajan and Stein (2008) propose that, rather than increasing capital requirements ex ante, firms buy contingent capital insurance: insurance that inserts capital in the bank when it gets into trouble, which essentially is analogous to the firm buying put options on its own stock. Their solution requires the existence of default-free entities that sell such insurance. As Duffie (2010) points out, if the source of distress is a general financial crisis, the put seller may itself be distressed and unable to honour its commitments. Bolton and Samama (2010) propose that banks buy puts from long-term investors such as sovereign wealth funds and other large institutional investors. It is again not obvious why these institutions would want to sell this insurance. Note that in the case of COERCs all investors in the world have an incentive to subscribe to the rights issue when the post-issue price is larger than the exercise price, not simply a number of long-term investors who has made a specific agreement with the bank in advance.

³⁸ See Bolton and Samama (2010, p.39).

The COERC trigger we propose in this paper is issuer specific. In contrast, Kashyap, Rajan and Stein (2008) propose a trigger mechanism based on aggregate bank losses. McDonald (2010) proposes a dual price trigger: conversion would be mandatory if the stock price falls below a trigger value *and* the value of a financial institutions stock index falls below another trigger. These proposals allow all financial institutions to recapitalize during a widespread financial crisis, but permit an individual institution to fail during normal times. A similar dual trigger mechanism is proposed by the Squam Lake Working Group (2009) proposal: banks would issue debt that would convert into equity when a regulator declares that there is a systematic crisis *and* the bank violates covenants. These approaches assume that the main purpose of CoCos is to mitigate the consequences of a major financial crisis, and because they assume that a regulator ultimately decides when conversion takes place, these CoCos may be hard to value. The goal of our paper is more general: to design a security that has the benefits of debt financing over equity financing but with lower financial distress costs than other debt securities. As a consequence, a COERC may be beneficial to any bank that wants to reduce shareholder – bondholder conflicts and avoid financial distress, regardless of a major systemic crisis.

A COERC should not be viewed as the sole instrument that prevents financial collapse, especially considering that the conversion of COERCs, as with other CoCos, does not infuse new funds into the bank. COERCs simply “clean up” the balance sheet and reduce the debt overhang and risk-shifting problems. These problems may be mitigated, but possibly not completely eliminated, if the bank has other senior debt or over-the-counter derivative liabilities. However, since COERCs are subordinated to these other senior liabilities, the larger the proportion of COERCs to these liabilities, the greater will be the reduction in risk-shifting and debt overhang. In addition, when conversion occurs at an early stage of financial distress, the resulting higher level of equity decreases the disincentive to issue additional equity or new COERCs.

7. Conclusions

In this paper we introduce and value a new security, the Call Option Enhanced Reverse Convertible (COERC). The security design modifies the CoCo proposal of Flannery

(2005, 2009a) to deal with three fundamental concerns. First, the security should not be an instrument to manipulate the issuing bank's stock price or cause a "death spiral" due to fears of massive dilution. COERCs avoid this problem by giving shareholders an option to buy back the shares from the COERC investors at the conversion price. Second, one cannot expect that there will be a very active market for CoCos if their investors are exposed to large risks. One way to reduce these investors' risks is to design their security in such a way that it forces shareholders to pay them back in cash when financial distress becomes significant. This is achieved with COERCs by setting the conversion price very low, below the stock price that will trigger the conversion. Not paying back the COERC investors would massively dilute shareholders and transfer wealth to COERC investors. This, in turn, lowers the credit risk of COERCs. Third, the security should be designed to rule out the problems of multiple- or no- equilibria pointed out by Bond, Goldstein and Prescott (2010) and analysed by Glasserman and Nouri (2012). Basing the conversion trigger on the market value of total capital to senior debt ratio, rather than the stock price, makes the COERC trigger robust to these potential problems.

Relative to standard CoCos, or even non-convertible bonds, COERCs' lower default risk mitigates the excessive risk-taking incentives that are typically present in a levered firm. The COERC design that reduces the possibility of wealth transfers between their investors and shareholders also helps solve the 'debt overhang' problem of high leverage described by Myers (1977). This reduction in agency costs should make the COERC design relevant for corporations in general.

Finally, unlike some other CoCos, with COERCs involvement by government regulatory authorities is not required. For example, Duffie (2010) proposes that regulators force a bank to make a deep discount rights issue whenever they consider it necessary. The COERC design also "forces" equity holders to repay debt in order to avoid dilution, but because this commitment is anticipated, it will benefit shareholders through lower yields on COERCs. Of course, in order to make a COERC interesting for issuers, interest should be tax deductible. It would be ironic if government policy handicapped debt that reduces the likelihood of a financial crisis while favouring standard debt that does not. Because

COERC investors are almost always repaid in cash, the tax authorities should look more favourably at a COERC than a standard CoCo.

Appendix

Derivation of the Deposit Credit Spread

The following is a derivation of the formula for h_t in equation (5). Define H_t as the value of the instantaneous loss per deposit conditional on a jump occurring. Then

$$\begin{aligned} H_t &\equiv E_t^Q \left[\max \left(\frac{D_t - Y_{q_t^-} A_{t^-}}{D_t}, 0 \right) \right] = E_t^Q \left[\max (1 - Y_t x_{t^-}, 0) \right] \\ &= \int_0^{1/x} (1 - Yx) \exp \left[-\frac{(\ln Y - \mu_y)^2}{2\sigma_y^2} \right] \frac{1}{Y\sigma_y \sqrt{2\pi}} dY \end{aligned} \quad (\text{A.1})$$

Make the change in variable $y \equiv (\ln Y - \mu_y)/\sigma_y$. Then $y|_{Y=0} = -\infty$, $y|_{Y=1/x} = -(\ln x + \mu_y)/\sigma_y$, $Y = \exp[\mu_y + y\sigma_y]$, and $dy = dY/(Y\sigma_y)$. Defining $d_1 \equiv [\ln x + \mu_y]/\sigma_y$, then

$$H_t = \int_{-\infty}^{-d_1} (1 - \exp[\mu_y + y\sigma_y] x) \frac{e^{-y^2/2}}{\sqrt{2\pi}} dy = N(-d_1) - x e^{\mu_y} \int_{-\infty}^{-d_1} \exp \left[y\sigma_y - \frac{y^2}{2} \right] \frac{1}{\sqrt{2\pi}} dy \quad (\text{A.2})$$

Completing the square in the exponent, one obtains

$$\int_{-\infty}^{-d_1} \exp \left[y\sigma_y - \frac{y^2}{2} \right] \frac{1}{\sqrt{2\pi}} dy = e^{\sigma_y^2/2} \int_{-\infty}^{-d_1} \frac{\exp \left[-\frac{1}{2} (y - \sigma_y)^2 \right]}{\sqrt{2\pi}} dy = e^{\sigma_y^2/2} \int_{-\infty}^{-d_2} \frac{e^{-y^2/2}}{\sqrt{2\pi}} dy \quad (\text{A.3})$$

where $d_2 = d_1 + \sigma_y \equiv [\ln x + \mu_y]/\sigma_y + \sigma_y$. Collecting terms together, one finds

$$H_t = N(-d_1) - x \exp \left[\mu_y + \frac{1}{2} \sigma_y^2 \right] N(-d_2) = N(-d_2) - \exp \left[\ln x + \mu_y + \frac{1}{2} \sigma_y^2 \right] N(-d_2) \quad (\text{A.4})$$

Multiplying H_t by the risk-neutral probability of a jump, λ , gives equation (5) in the text.

Monte Carlo Simulation Method

The following describes the risk-neutral valuation method for the case where bank assets are observed with noise. Valuation for the basic model without noise is a special case with the noise term, η_t , set to zero.

The risk-neutral process for the fundamental value of the bank's assets, A_t , equals the assets' risk-neutral rate of return plus deposit growth less the payouts of interest to depositors and dividends to shareholders. In addition, as long as bonds remain unconverted, payouts include bond coupons. Thus, if $A_t e^{\eta_t}$ equals the observed (with noise) bank asset value, the actual (fundamental) asset value follows the process

$$\begin{aligned}
dA_t &= \left(dA_t^* / A_t^* \right) A_t + dD - (r_t + h_t) D_t dt - c_t B - \delta (A_t e^{\eta_t} - B - D_t) dt \\
&= \left[(r_t - \lambda k - \delta e^{\eta_t}) A_t + \left(g(x_t e^{\eta_t} - \hat{x}) - r_t - h_t + \delta \right) D_t - (c_t - \delta) B \right] dt \\
&\quad + \sigma A_t dz + \left(Y_{q_t^-} - 1 \right) A_t dq
\end{aligned} \tag{A.5}$$

where we have substituted in equations (2) and (4). Equation (A.5) can be rewritten as

$$\frac{dA_t}{A_t} = \left[r_t - \lambda k - \delta e^{\eta_t} + \frac{g(x_t e^{\eta_t} - \hat{x}) - r_t - h_t + \delta - (c_t - \delta) b_t}{x_t} \right] dt + \sigma dz + \left(Y_{q_t^-} - 1 \right) dq \tag{A.6}$$

where $b_t \equiv B/D_t$. Thus, the risk-neutral process for the asset/deposit ratio is

$$\begin{aligned}
dx_t / x_t &= dA_t / A_t - dD_t / D_t \\
&= \left[r_t - \lambda k - \delta e^{\eta_t} + \frac{g(x_t e^{\eta_t} - \hat{x}) - r_t - h_t + \delta - (c_t - \delta) b_t}{x_t} - g(x_t e^{\eta_t} - \hat{x}) \right] dt \\
&\quad + \sigma dz + \left(Y_{q_t^-} - 1 \right) dq
\end{aligned} \tag{A.7}$$

A simple application of Itô's lemma for jump-diffusion processes implies

$$\begin{aligned}
d \ln x_t &= \left[r_t - \lambda k - \delta e^{\eta_t} + \frac{g(x_t e^{\eta_t} - \hat{x}) - r_t - h_t + \delta - (c_t - \delta) b_t}{x_t} - g(x_t e^{\eta_t} - \hat{x}) - \frac{\sigma^2}{2} \right] dt \\
&\quad + \sigma dz + \ln Y_{q_t^-} dq
\end{aligned} \tag{A.8}$$

Note that in equation (A.8), when bonds are assumed to pay floating coupons, $c_t = r_t + s$. Also, when bank assets are observed with noise, the deposit credit spread, h_t , is given by equation (5) in the text but with x_t replaced by $x_t e^{\eta_t}$. Furthermore, a trivial application of Itô's lemma shows that $b_t = B/D_t$ evolves as

$$db_t / b_t = g(\hat{x} - x_t e^{\eta_t}) dt \tag{A.9}$$

To value subordinated debt or a CoCo or COERC bond, we compute the expression

$$V_0 = E_0^Q \left[\int_0^T e^{-\int_0^t r_s ds} \nu(t) dt \right] \tag{A.10}$$

where $\nu(t)$ is the bond's cash flow per unit time paid at date t . $\nu(t) = c_t B = (r_t + s)B$ as long as the bond is not converted or the bank has not failed. If date T is reached without the bond converting or the bank failing, there is a final cash flow of B . Given equation (7), conversion of a CoCo or COERC is triggered the first time that the observed capital to deposit ratio falls below the trigger threshold:

$$x_t e^{\eta_t} - 1 \leq \chi \tag{A.11}$$

In this case, there is a final cash flow given by equation (1). For the case of subordinated debt, bank failure occurs the first time that the par value of total debt exceeds observed assets, or $x_t e^{\eta_t} \leq 1 + b_t$. In that case, subordinated debt holders receive a final cash flow of $\min\{B, \max[A_t - D_t, 0]\}$.

The right-hand side of equation (A.10) is calculated using a technique similar to Zhou (2001), which is a discretization method for Monte Carlo valuation of a mixed jump-diffusion process. We generalize his approach for the case of our four state variables: the default-free short rate, r_t , which follows the process (4); the asset/deposit ratio, x_t , which satisfies the jump-diffusion process (A.8); the bond par value/deposit ratio, b_t , which follows the process (A.9); and noise, η_t , which follows the process (10).

Divide the time interval $[0, T]$ into n equal sub-periods, where $\Delta t \equiv T/n$ is the length of each period. n is chosen to be relatively large so that a small Δt leads to an accurate discrete-time approximation of the model's continuous-time processes. With time measured in years, our empirical work assumes $\Delta t \equiv 1/250$, the length of one trading day.

Let t denote the end of trading day $t - \Delta t$ and the beginning of trading day t . Then the discrete-time process corresponding to (4) is

$$\begin{aligned} r_{t+\Delta t} &= r_t + \kappa_r (\bar{r} - r_t) \Delta t + \sigma_r \sqrt{r_t} \sqrt{\Delta t} \xi_{t+\Delta t} \\ &= \bar{r} \kappa_r \Delta t + r_t (1 - \kappa_r \Delta t) + \sigma_r \sqrt{r_t} \sqrt{\Delta t} \xi_{t+\Delta t} \end{aligned} \quad (\text{A.12})$$

where $\xi_{t+\Delta t} \sim N(0, 1)$ are serially independent shocks representing Brownian motion uncertainty. Similarly, the discrete-time process corresponding to (A.8) is

$$\begin{aligned} \ln x_{t+\Delta t} &= \ln x_t + \left[r_t - \lambda k - \delta e^{\eta_t} + \frac{g(x_t e^{\eta_t} - \hat{x}) - r_t - h_t + \delta - (c_t - \delta) b_t}{x_t} - g(x_t e^{\eta_t} - \hat{x}) - \frac{\sigma^2}{2} \right] \Delta t \\ &\quad + \sigma \sqrt{\Delta t} \varepsilon_{t+\Delta t} + \ln Y_{t+\Delta t} \varphi_{t+\Delta t} \end{aligned} \quad (\text{A.13})$$

where $\varepsilon_{t+\Delta t} \sim N(0, 1)$ are serially independent shocks, $E_t^Q[\varepsilon_{t+\Delta t} \xi_{t+\Delta t}] = \rho$, $\ln Y_{t+\Delta t} \sim N(\mu_y, \sigma_y^2)$, and

$$\varphi_{t+\Delta t} = \begin{cases} 1 & \text{with probability } \Delta t \lambda \\ 0 & \text{with probability } 1 - \Delta t \lambda \end{cases} \quad (\text{A.14})$$

Finally, the discrete-time analogues of equations (A.9) and (10) are

$$b_{t+\Delta t} = b_t \exp \left[-g(x_t e^{\eta_t} - \hat{x}) \Delta t \right] \quad (\text{A.15})$$

$$\eta_{t+\Delta t} = (1 - \kappa_\eta \Delta t) \eta_t + \sigma_\eta \sqrt{\Delta t} \varpi_{t+\Delta t} \quad (\text{A.16})$$

where $\varpi_{t+\Delta t} \sim N(0, 1)$ are serially independent shocks uncorrelated with $\xi_{t+\Delta t}$ and $\varepsilon_{t+\Delta t}$. A Each Monte Carlo simulation of (A.12), (A.13), (A.15), and (A.16) calculates a realization of the right-hand side of (A.10), and taking the average of at least 100,000 of them gives V_0 for a given spread, s . s is varied until the (fair) one is found where $V_0 = B$.

References

- Adrian, T. and H. S. Shin, 2010, Liquidity and leverage, *Journal of Financial Intermediation* 20, 418-437.
- Albul, B., D. Jaffee and A. Tchistyi, 2010, Contingent convertible bonds and capital structure decisions, working paper, University of California, Berkeley.
- Barucci, E. and L. Del Viva, 2011, Dynamic capital structure and the contingent capital option, *Annals of Finance* (forthcoming).
- Basel Committee on Banking Supervision, 2011, Global systematically important banks: Assessment methodology and the additional loss absorbency requirement, Bank for International Settlements, November.
- Berg, T. and C. Kaserer, 2011, Does contingent capital induce excessive risk-taking and prevent an efficient recapitalization of banks? working paper, Humboldt University and Technical University Munich.
- Bolton, P. and F. Samama, 2010, Contingent capital and long term investors: a natural match?, conference paper, Columbia University Committee on Global Thought.
- Boyle, P., 1977, Options: A Monte Carlo approach, *Journal of Financial Economics* 4, 323-328.
- Bühler, W. and M. Trapp, 2009, Time-varying credit risk and liquidity premia in bond and CDS markets, working paper.
- Calomiris, C. and R. Herring, 2011, Why and how to design a contingent convertible debt requirement, working paper, Columbia University and University of Pennsylvania.
- Collin-Dufresne, P. and R. Goldstein, 2001, Do credit spreads reflect stationary leverage ratios? *Journal of Finance* 56, 1929-1957.
- Cox, J., J. Ingersoll, and S. Ross, 1985, A theory of the term structure of interest rates, *Econometrica* 53, 385-408.
- De Groen, W. P., 2011, A closer look at Dexia: the case of misleading capital ratios, CEPS Commentary, October.
- De Jonghe, O., 2010, Bank to the basics in banking? A micro-analysis of banking system stability, *Journal of Financial Intermediation* 19, 387-417.
- Demsetz, R. and P. Strahan, 1997, Diversification, size, and risk at U.S. bank holding companies, *Journal of Money, Credit, and Banking* 29, 300-313.

- Duan, J.-C. and J.-G. Simonato, 1999, Estimating and testing exponential-affine term structure models by Kalman filter, *Review of Quantitative Finance and Accounting* 13, 111-135.
- Duffie, D., 2010, A contractual approach to restructuring financial institutions, Chapter 6 of George Schulz, Kenneth Scott, and John Taylor (eds.) *Ending Government Bailouts as We Know Them*, Hoover Press.
- Flannery, M., 2005, No pain, no gain: Effecting market discipline via reverse convertible debentures, in Hal S. Scott (ed.) *Capital Adequacy beyond Basel: Banking, Securities and Insurance*, Oxford: Oxford University Press.
- Flannery, M., 2009a, Market value triggers will work for contingent capital investments, working paper, University of Florida.
- Flannery, M., 2009b, Stabilizing large financial institutions with contingent capital certificates, working paper, University of Florida.
- Flannery, M., 2010, A fix to the death spiral problem, mimeo, University of Florida.
- Flannery, M. and K. Rangan, 2008, What caused the bank capital build-up of the 1990s?, *Review of Finance* 12, 391-429.
- Glasserman, P. and B. Nouri, 2010, Contingent capital with a capital ratio trigger, *Management Science*, (forthcoming).
- Glasserman, P. and B. Nouri, 2012, Market-Triggered Changes in Capital Structure: Equilibrium Price Dynamics, working paper, Columbia University.
- Haldane, A., 2011, Capital discipline, paper presented at American Economic Association Meetings, Denver CO, January 9.
- HM (UK) Treasury, 2009, Risk, reward and responsibility: the financial sector and society, available at hm-treasury.gov.uk.
- Hillion, P. and T. Vermaelen, 2004, Death spiral convertibles, *Journal of Financial Economics* 71, 381-415
- Hilscher, J. and A. Raviv, 2011, Bank stability and market discipline: The effect of contingent capital on risk taking and default probability, working paper, Brandeis University.
- Jensen, M. and W. Meckling, 1976, Theory of the firm, managerial behaviour, agency costs and ownership structure, 3, 305-360

- Jurek, J. and H. Yang, 2007, Dynamic Portfolio Selection in Arbitrage, working paper, Harvard University.
- Kasyhap, A., R. Rajan, and J. Stein, 2008, Rethinking capital regulation, Federal Reserve Bank of Kansas City Economic Symposium on *Managing Stability in a Changing Financial System*.
- Memmel, C. and P. Raupach, 2010, How do banks adjust their capital ratios?, *Journal of Financial Intermediation* 19, 509-528.
- Merrouche, O. and M. Mariathasan, 2012, The manipulation of base risk weights : evidence from 2007-2010, EUI and Oxford University working paper.
- Merton, R., 1974, On the pricing of corporate debt: The risk structure of interest rates, *Journal of Finance* 29, 449-470.
- McDonald, R., 2010, Contingent capital with a dual price trigger, working paper, Northwestern University
- Myers, S., 1977, Determinants of corporate borrowing, *Journal of Financial Economics* 5, 147-175.
- Myers, S., and N. Majluf, 1984, Corporate financing and investment decisions when firms have information that investors don't have, *Journal of Financial Economics* 13, 187-221.
- Pan, J., 2002, The jump-risk premia implicit in options: Evidence from an integrated time-series study, *Journal of Financial Economics* 63, 3-50.
- Pennacchi, G., 2011, A structural model of contingent bank capital, Federal Reserve Bank of Cleveland Working Paper 10-04. Available at <http://business.illinois.edu/gpennacc/ConCap061811.pdf>.
- Pennacchi, G., 2000, The effects of setting deposit insurance premiums to target insurance fund reserves, *Journal of Financial Services Research* 17, 153-180.
- Rosenthal, L. and C. Young, 1990, The seemingly anomalous price behavior of Royal Dutch Shell and Unilever nv/plc, *Journal of Financial Economics* 26, 123-141.
- Squam Lake Working Group, 2009, An expedited resolution mechanism for distressed financial firms: regulatory hybrid securities, Council on Foreign Relations.
- Zhou, C., 2001, The term structure of credit spreads with jump risk, *Journal of Banking and Finance* 25, 2015-2040.

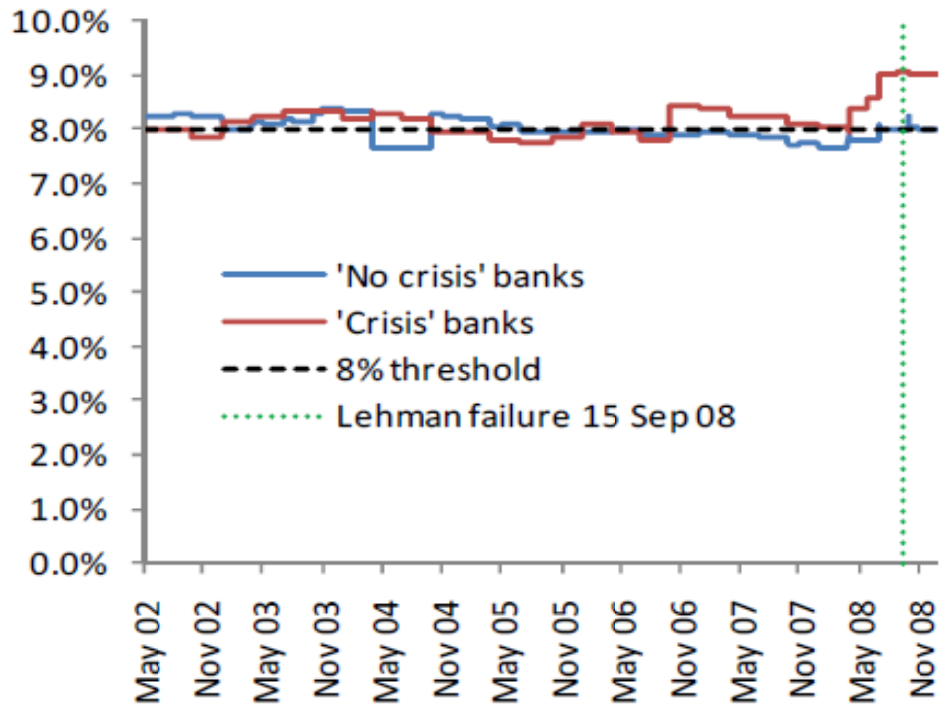
Table 1
Daily Trading Statistics for Subordinated Debt of Major US Banks
2007 to 2011

	Bank of America		Citigroup		JP Morgan Chase	
	Trades	\$ Volume	Trades	\$ Volume	Trades	\$ Volume
Average	33.4	2674066	33.3	4965545	32.9	3979899.8
Standard Deviation	27.8	4338850	23.5	7664606	19.4	5863343.9
1 Percentile	1	13880	3	55880	5	30000
5 Percentile	5	101350	11	299850	10	242000
25 Percentile	13	533750	20	1164750	20	756000
50 Percentile	26	1258000	28	2428500	30	1746000
75 Percentile	47	2963750	40	5853750	42	5002750
95 Percentile	85	9562050	75	16686150	66	14780900
99 Percentile	122	20980080	119	32975180	86	30608380
Median 2007	9	538000	22	1742000	15	2367000
Median 2008	14	708000	27	1666000	30	1556000
Median 2009	44	1916500	47	5032500	39	1597500
Median 2010	43	2050500	30	2428500	37	2344500
Median 2011	33	1571500	27	2331000	31.5	1503500
Total Days With Zero Trading	9		6		5	

Note: The table's trading statistics are computed from January 2, 2007 to December 30, 2011 TRACE data. TRACE does not specify the dollar amount for transactions exceeding \$5 million. In those cases we assume a transaction of \$5 million. The statistics are for the following bonds. Bank of America: 12-year subordinated note issued December 2003 with 5.25% semi-annual coupon, cusip 060505BG8. Citigroup: 10-year subordinated note issued August 2002 with 5.625% semi-annual coupon, cusip 172967BP5. JP MorganChase 10-year subordinated note issued October 2005 with 5.15% semi-annual coupon, cusip 46625HDF4.

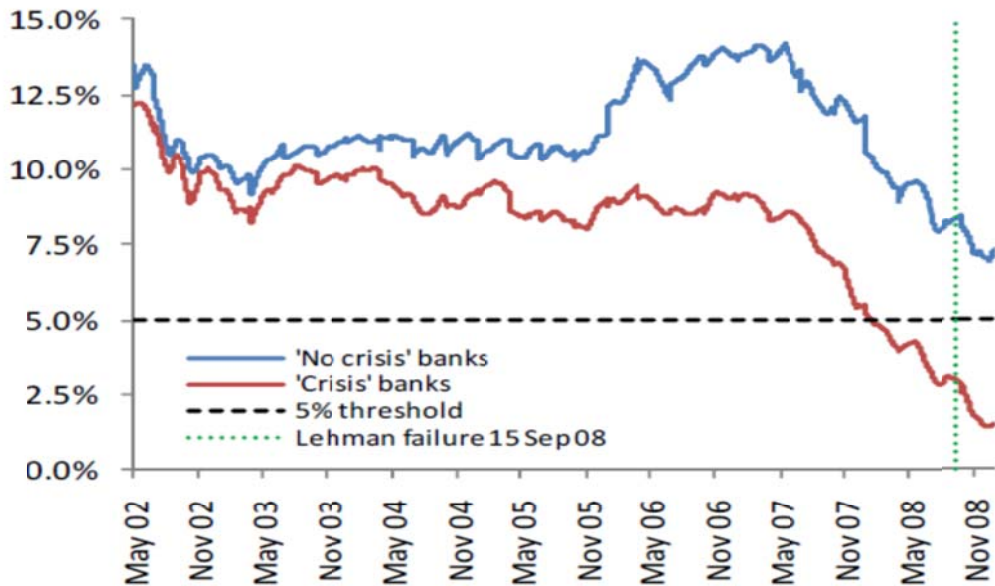
Figure 1 Tier 1 Capital Ratios versus Market Capital Ratios

A. Tier 1 capital ratios for “crisis” and “no crisis” banks (Haldane (2011), p.14)



Sources: Capital IQ and Bank calculations

B. Market capitalisation to book-value of debt (Haldane (2011), p.15)



Sources: Capital IQ and Bank calculations

Figure 2 Credit Spreads of Subordinated Debt, CoCos, and COERCs

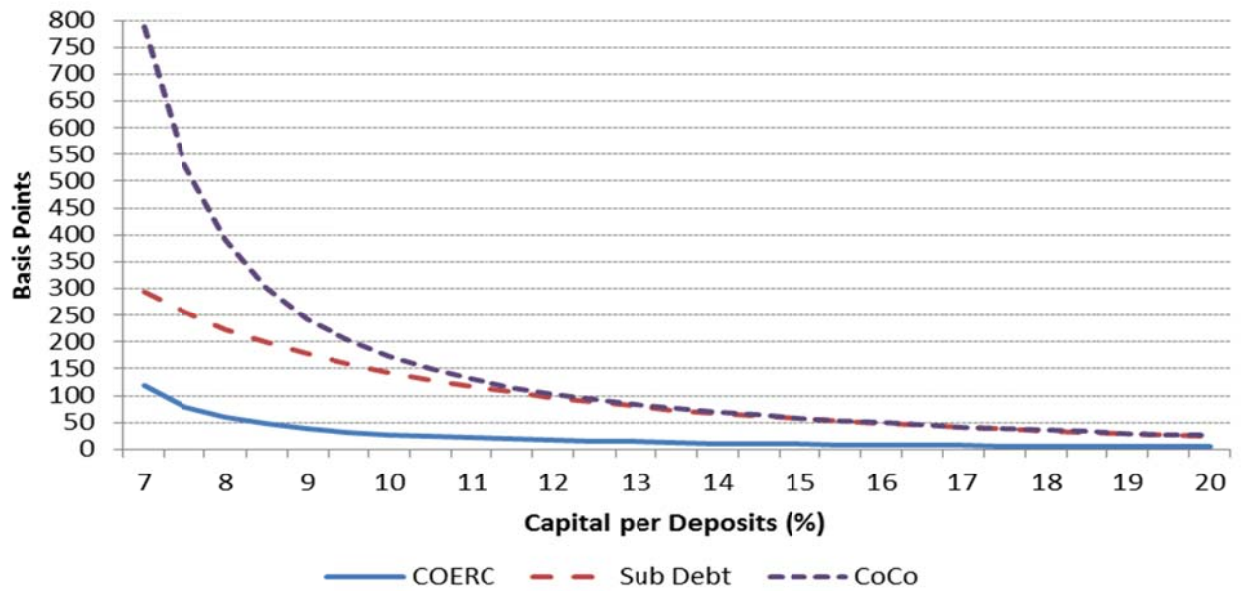


Figure 3 COERC Credit Spreads by Dilution Ratio, α

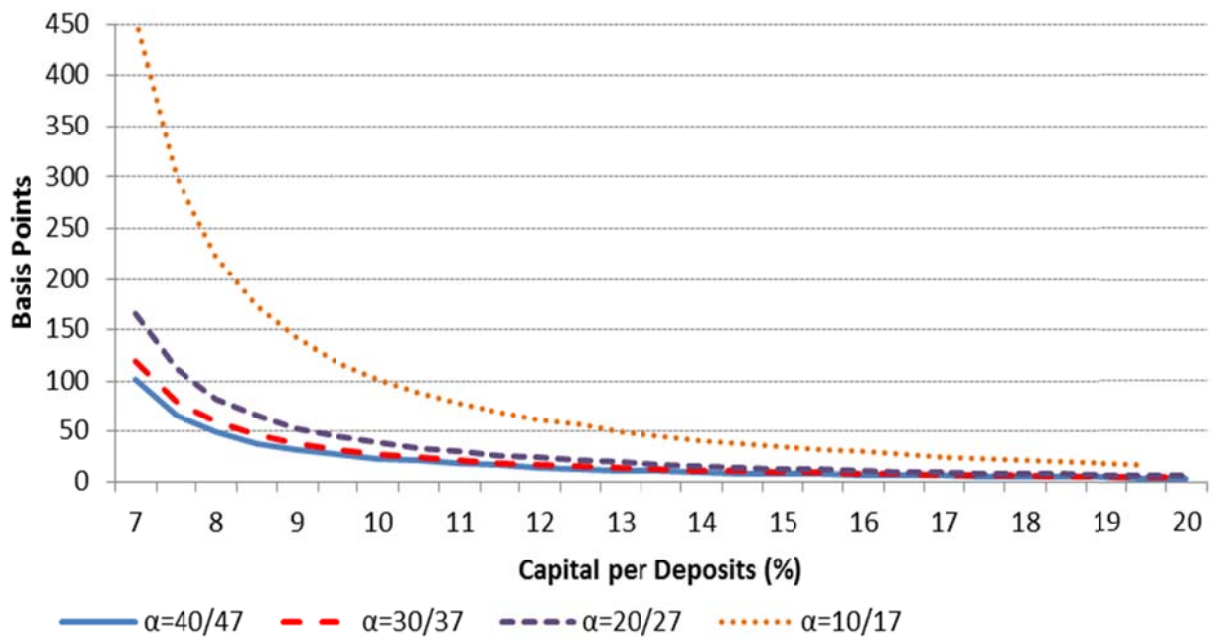


Figure 4 COERC Credit Spreads by Trigger Threshold, χ

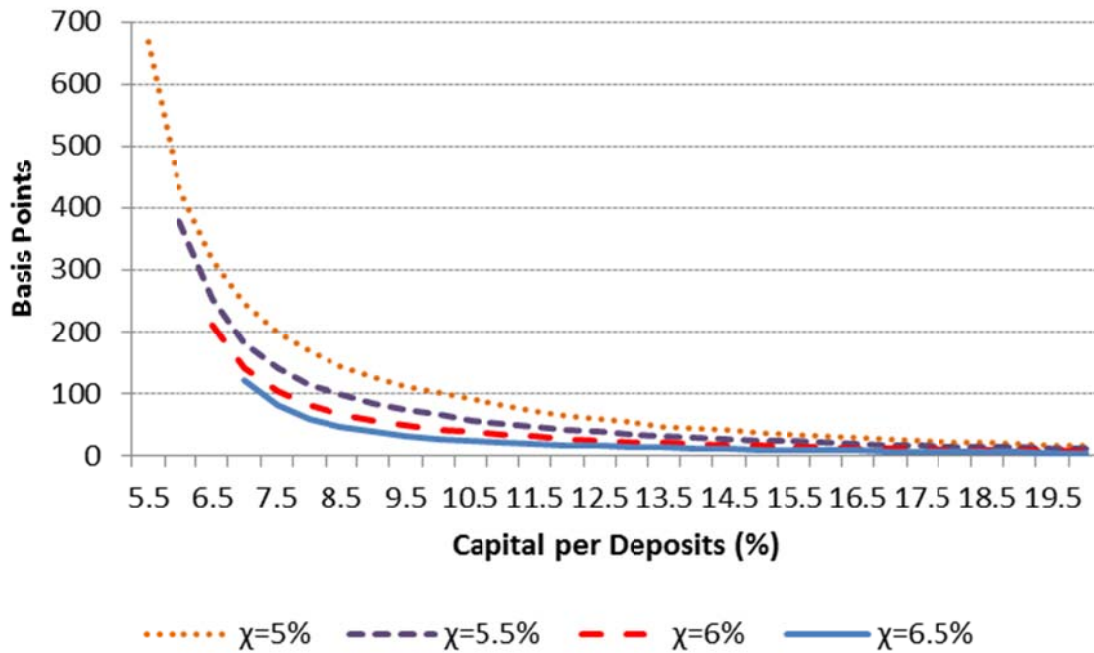


Figure 5 Risk-Shifting Incentives when Banks Issue Subordinated Debt, CoCos, and COERCs

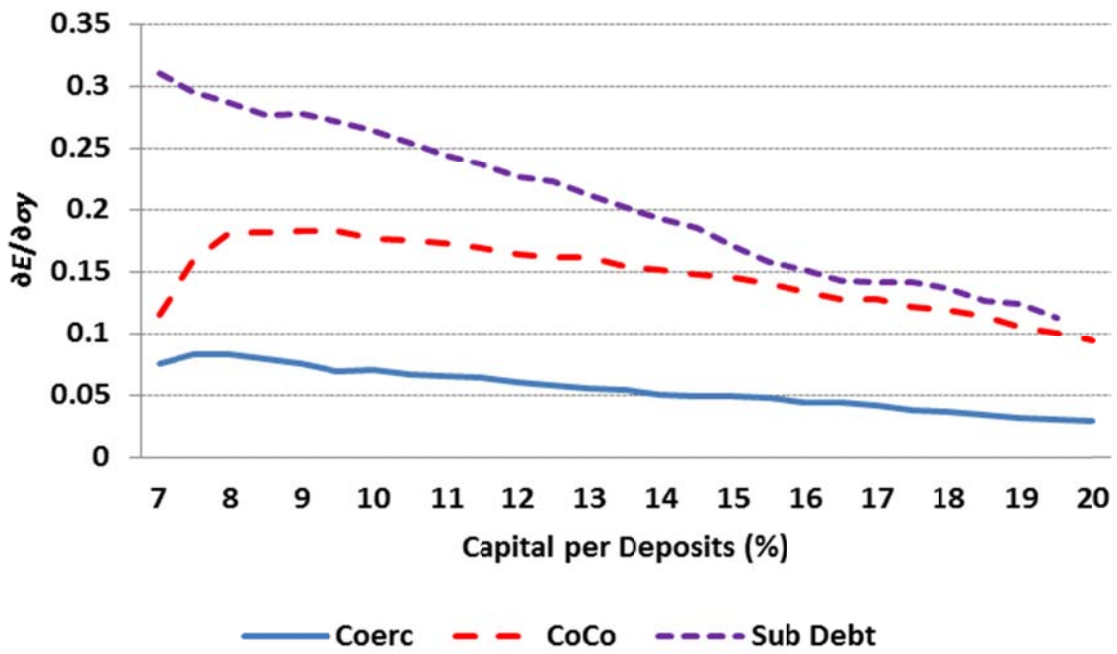


Figure 6 Debt Overhang when Banks Issue Subordinated Debt, CoCos, and COERCs

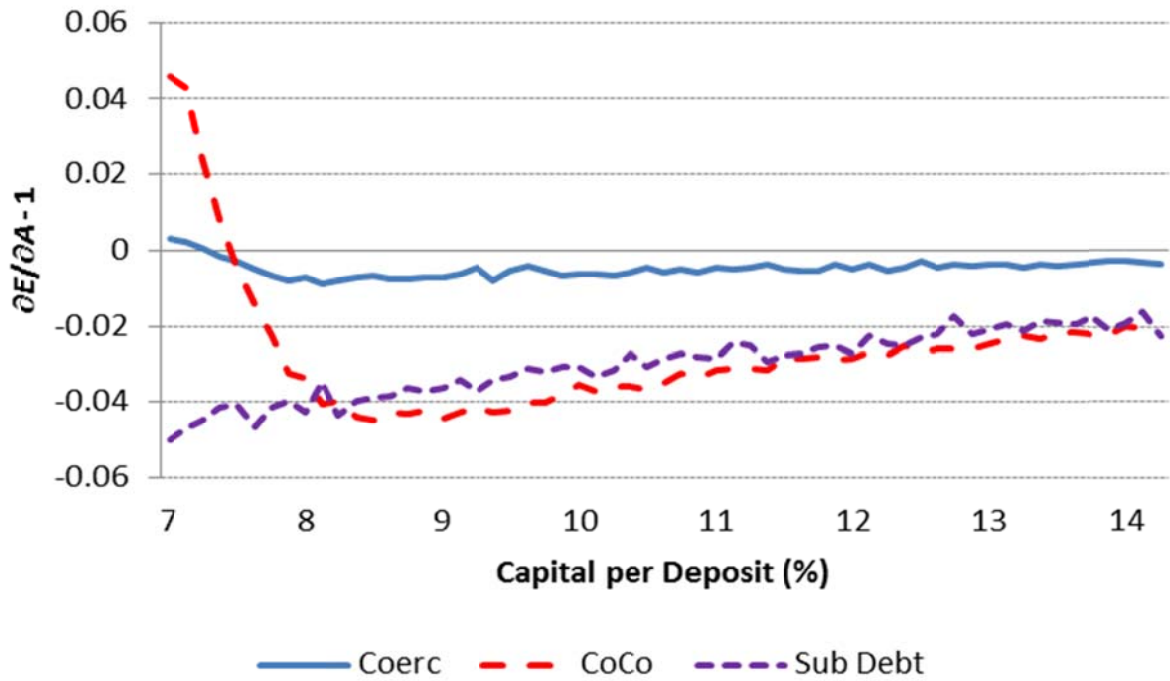


Figure 7 Credit Spreads for CoCos and COERCs: The Effect of Noise

