Contingent Capital, Tail Risk and Debt-Induced Collapse

Markus Pelger $^1$
(Nan Chen $^2$ Paul Glasserman $^3$ Behzad Nouri $^4$)

$^1$University of California, Berkeley
$^2$Chinese University of Hong Kong
$^3$Columbia University and U.S. Office of Financial Research
$^4$Columbia University

Stanford University
Management Science & Engineering
January 15, 2015
Contingent Convertible Bonds

Contingent convertibles (CoCos)

- Contingent convertibles (CoCos) are debt that automatically converts to equity when a firm gets in trouble
- Regulatory security to recapitalize distressed banks

Motivation

- A built-in mechanism to increase capital when it is most needed and difficult to raise
- Reduce a bank’s default risk during financial distress
  - reduce a bank’s coupon payments
  - banks gain an extra cushion of loss-absorbing equity capital
- Need for automatic recapitalization: Without CoCos banks were unwilling to raise equity during the crisis and instead sold assets
Motivation (continued)

- A promising solution to the problem of banks “too-big-to-fail”:
  - avoid government bail-out (more risky strategies, costly to taxpayer)
  - shifting risk-incentives:
    - CoCo investors share some of the bank’s downside risk without triggering failure
- Dilution effect in conversion can create incentives for managers and equity holders to
  - reduce risk
  - invest into the bank
- Higher capital requirements also reduce default probability, but
  - different incentives
  - no automatic recapitalization conditional on approaching insolvency
CoCos: going-concern contingent capital: conversion well before default; partially diluting the original shareholders.

Bail-In: gone-concern contingent capital: conversion at default; wiping out the original equity holder by a reorganization.
Current Status in Practice

Important element of financial stability reform

- The Swiss banking regulator has increased capital requirements to 19%, of which 9% can take the form of CoCos.
- European Banking Authority allows CoCos to qualify as Tier 1 regulatory capital under certain restrictions.
- In the U.S. Dodd-Frank act: bail-in is central to the implementation of the FDICs authority to resolve too-big-to-fail banks.

Issuances of CoCos

- Rabobank, UBS, Barclays, KPC: alternative structure with debt write-down.

⇒ More interest in Europe than the U.S.
Examples of Issued CoCos

<table>
<thead>
<tr>
<th>Issuer</th>
<th>Lloyds</th>
<th>Credit Suisse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full name</td>
<td>Enhanced Capital Notes (ECN)</td>
<td>Buffer Capital Notes (BCN)</td>
</tr>
<tr>
<td>Issue Size</td>
<td>GBP 7 bn</td>
<td>USD 2 bn</td>
</tr>
<tr>
<td>Issue Date</td>
<td>December 1, 2009</td>
<td>February 17, 2011</td>
</tr>
<tr>
<td>Maturity</td>
<td>10-20 years</td>
<td>30 years</td>
</tr>
<tr>
<td>Coupon</td>
<td>1.5%-2.5% increase of the coupon of the hybrid bond exchanged for ECN</td>
<td>7.875%</td>
</tr>
<tr>
<td>Trigger</td>
<td>Conversion into a fixed number of shares</td>
<td>Conversion into a fixed number of shares</td>
</tr>
<tr>
<td>Conversion Price</td>
<td>59 Pence</td>
<td>max(USD 20, CHF 20)</td>
</tr>
<tr>
<td>Trigger Type</td>
<td>Accounting</td>
<td>Accounting and Regulatory</td>
</tr>
<tr>
<td>Accounting Trigger</td>
<td>Core Tier 1 Ratio</td>
<td>Core Tier 1 Ratio</td>
</tr>
<tr>
<td>Accounting Trigger Level</td>
<td>5%</td>
<td>7%</td>
</tr>
</tbody>
</table>

More issues by Rabobank, ZKB, UBS, Barclays, KBC, Bank of Ireland
Research Question: Incentives

Research question:
What are the incentive effects of CoCos (and bail-in debt) and what drives these effects?

Incentives:

- How do CoCos affect the
  - *optimal bankruptcy boundary* for equity holders?
  - *debt overhang costs*
    - the reluctance of equity holders to invest in a highly leveraged firm as its assets lose value?
  - *asset substitution*
    - the propensity of equity holders to choose riskier assets after issuing debt?

- How do endogenous default, debt maturity, tax treatment, bankruptcy costs, and tail risk influence the answers to these questions?
This Paper

Key Contributions and Conclusions

**Model**

Our structural credit risk model combines

- Endogenous default
- Debt roll-over at various maturities and levels of seniority
- Jumps and diffusion in cash flows and asset values

**Results**

Through these features, CoCos can create incentives for shareholders to

- Reduce default risk (through capital structure and asset riskiness)
- Invest in the firm to prevent conversion
- Potentially take on additional tail risk

⇒ These positive features rely on avoiding *debt-induced collapse*
   (debt-induced collapse = default happens before conversion)
Related Research (Partial List)

- Flannery (2005, 2009):
  ⇒ Proposed reverse convertible debentures with a market trigger

- Albul, Jaffee and Tchistyì (2010); Hilscher and Raviv (2011); Himmelberg and Tsyplakov (2012):
  ⇒ Diffusion models, infinite-maturity/single-maturity debt

- Pennacchi (2010):
  ⇒ Jump-diffusion simulation model, incentives, exogenous default

- McDonald (2010), Sqam Lake Working Group (2010):
  ⇒ Dual trigger: bank-specific and/or systemic

  ⇒ Viability of market triggers
Schematic of the Model

Value of the firm’s assets over time

Equity and debt valued as contingent claims on underlying asset value
Model Overview

- Firm’s value process $V_t$ follows an exogenous jump diffusion process under the martingale measure $\mathbb{Q}$
- No-arbitrage pricing: prices are expected values of the discounted payoffs under the martingale measure $\mathbb{Q}$
- Bank issues equity, straight debt and CoCos (more complex capital structure in paper: deposit, debt of different seniority)
- Chen and Kou (2009) model for straight debt
- Stationary debt structure:
  - debt is constantly issued and retired such that the total face value of debt stays constant
  - coupon payment is constant
    $\Rightarrow$ total coupon and total face value of debt constant over time
- Endogenous default barrier: optimal $V_B$ maximizes the equity value subject to the non-liability constraint (Leland (1994))
Dynamics of State Variable

Dynamics of $V_t$:

- Value of the firm’s assets $V_t$ under the martingale measure $\mathbb{Q}$ follows an exponential Kou process:

$$\frac{dV_t}{V_{t^-}} = (r - \delta) dt + \sigma dW_t + d\left(\sum_{i=1}^{N_t} (Y_i - 1)\right) + \frac{\lambda}{1 + \eta} dt$$

- $W_t$ Brownian motion
- $N_t$ Poisson process with intensity $\lambda$
- $-\log(Y_i)$ follows an exponential distribution with average $\frac{1}{\eta}$
- $r$ constant riskless interest rate
- $\delta$ cash flow (dividends + debt payments)
- all stochastic processes are independent

$\Rightarrow$ Closed-form solutions for transformations of first-passage times
Chen and Kou (2009) Model for Straight Debt

**Straight Debt (≡ regular debt)**

- Total par value of straight debt $P_D$
- Default time: $\tau_b = \inf\{t \in (0, \infty) : V_t \leq V_b\}$
- Market value of total debt given asset value $V$:
  \[ B(V, V_b) = \text{coupons} + \text{face value repayment} + \text{recovery payment} \]
- Rollover structure of finite-maturity debt
Chen and Kou (2009) Model for Straight Debt (continued)

Equity for a post-conversion firm (only straight debt, no CoCos)

\[ EQ^{PC}(V, V_b) = V_{ul} + TB_D - BCOST - B \]

- tax benefits: \[ TB_D(V, V_b) = P_D \cdot \mathbb{E}^Q \left[ \int_0^{\tau_b} \kappa c_D e^{-rt} dt \right] \]
- \( \kappa \) corporate tax rate
- \( c_D \) constant coupon rate
- bankruptcy costs: \[ BCOST(V, V_b) = \mathbb{E}^Q \left[ (1 - \alpha) V_{\tau_b} e^{-r\tau_b} \right] \]
- expectation under the martingale measure \( Q \).
Conversion of CoCo Bonds

Conversion

- Conversion time: $\tau_C = \inf\{ t \in (0, \infty) : V_t \leq V_C \}$

- General approach:
  captures any invertible function of state variable $V_t$:
  - Common equity (accounting notion): $V_t - P_D - P_C$.
  - Convert when $\frac{V_t - P_D - P_C}{V_t} \leq \rho$, i.e.
    $$V_C = \frac{P_D + P_C}{(1 - \rho)}$$

- At conversion CoCo investors receive $n'$ share for each CoCo for a total of $n'P_C$ shares

- $n = \text{number of shares prior to conversion}$

- After conversion CoCo investors own $\frac{n'P_C}{n + n'P_C}$ of the equity
Evaluation of CoCo Bonds

Unit bond (if $V_b < V_c$)

Value of a single CoCo with face value 1 and maturity $t$ (if $V_b < V_c$):

$$d(V, V_b, V_c, t) = \mathbb{E}_Q^Q \left[ \int_0^{t \wedge \tau_c} c_C e^{-rs} ds \right] + \mathbb{E}_Q^Q \left[ e^{-rt} \mathbb{1}_{\{t < \tau_c\}} \right]$$

- **coupon payments**
- **face value repayment**

$$+ \frac{n'}{n + n' P_C} \mathbb{E}_Q^Q \left[ EQ^{PC}(V_{\tau_c}) e^{-r \tau_c} \mathbb{1}_{\{\tau_c \leq t\}} \right]$$

- **conversion value**

- **conversion time**: $\tau_C = \inf\{t \in (0, \infty) : V_t \leq V_C\}$
- $c_C = \text{constant coupon rate}$
- $P_C = \frac{p_C}{m} = \text{total face value}$
- $n' = \text{number of shares for CoCo holder at conversion}$
- $n = \text{number of old shares at conversion}$
Rolling debt structure: (Leland (94), Chen&Kou (09))

- firm issues new CoCos in the amount $p_C dt$ in $(t, t + dt)$.
- maturity profile $me^{-st}$ (i.e. there is a portion $me^{-ms} p_C ds$ of $p_C dt$ due in the interval $(t + s, t + s + ds)$)
- average maturity of debt $\int_0^\infty tme^{-mt} dt = \frac{1}{m}$

$\Rightarrow$ constant face value of CoCos: $P_C = p_C \int_0^\infty e^{-mt} dt = \frac{p_C}{m}$

Total value of all CoCos (if $V_b < V_c$)

$$D(V, V_b, V_c) = P_C \int_0^\infty me^{-mt} d(V, V_b, V_c, t) dt$$
Evaluation of CoCo Bonds

**Equity value before conversion**

\[ EQ^{BC} = V + TB - BCOST - B - D \]

- **unleveraged firm value**
- **total tax benefits**
- **bankruptcy costs**
- **debt**
- **CoCos**

- **total tax benefits:** \( TB = TB_D + TB_C \)
- **tax benefits:** \( TB_C(V, V_b) = P_C \cdot E^Q \left[ \int_0^{\tau_c} \kappa C_C e^{-rt} dt \right] \)
- **\( \kappa \) corporate tax rate**

**Calculation**

Explicit evaluation through expressions for the joint transforms of hitting times \( \tau_b, \tau_c \) and \( V \)
Endogenous Default: Optimization Problem

Endogenous Default with CoCos

Endogenous default

- Two regimes for default decision:
  - "good case": conversion before default
  - "debt-induced collapse": default before conversion
- An increase in debt can move the firm from the first regime to the second regime

Optimization problem of shareholders without CoCos

- When the firm faces a cash shortfall, equity holders choose either to invest further or to abandon the firm
- Shareholders choose $V_b^{PC}$ to maximize the equity value

$$\max_{V_b} EQ^{PC}(V, V_b) \quad \text{s.t.} \quad EQ^{PC}(V', V_b) > 0 \text{ for all } V' > V_b$$

subject to the limited liability constraint.
Endogenous Default: Optimization Problem

Endogenous Default with CoCos

Optimization problem of shareholders with CoCos

- Shareholders with CoCos choose $V_{b}^{BC}$ to optimize the equity value

$$\max_{V_{b}} EQ^{BC}(V, V_{b}) \quad \text{s.t. } EQ^{BC}(V', V_{b}) > 0 \text{ for all } V' > V_{b}$$

subject to the commitment condition $V_{b} = V_{b}^{PC}$ if $V_{b} < V_{c}$.

3 Cases:

Consider three otherwise identical firms:

- **Post-conversion firm**: default barrier $V_{b}^{PC}$, only straight debt
- **Before conversion firm**: default barrier $V_{b}^{BC}$, straight debt and CoCos
- **No-conversion firm**: default barrier $V_{b}^{NC}$, CoCos degenerated to junior straight debt
Debt-Induced Collapse: Illustration

Equity Value and Default: Good Case

Good case: $V_b^{PC}$ is feasible
$V_b^{PC}$ is not feasible as it violates the limited liability condition.
Debt-Induced Collapse: Illustration

Debt-Induced Collapse

- \( V_b^{NC} \) is feasible and optimal choice
- Equity value jumps down, default risk jumps up
Critical Level of Debt for Debt-Induced Collapse

Theorem 1: Optimal Default Barrier $V_B$ with CoCos:

For a firm with straight debt and with CoCos that convert at $V_c$, the optimal default barrier $V_{b}^{BC}$ has the following property: Either

$$V_{b}^{BC} = V_{b}^{PC} \quad \text{or} \quad V_{b}^{BC} = V_{b}^{NC}$$

given that $V_{b}^{NC} > V_c$

$V_{b}^{PC}$ is optimal whenever it is feasible.

Implications

- A high conversion trigger can avoid debt-induced collapse.
- Under debt-induced collapse, CoCos degenerate to junior straight debt and cannot achieve their positive regulatory objectives.
- Bail-in debt avoids debt-induced collapse.
- Debt-induced collapse is not possible under a stock price trigger.
Debt-Induced Collapse: Theorems

Critical Level of Debt for Debt-Induced Collapse

Reasons for debt-induced collapse:

1. $V_b^{PC} > V_c$:
   Post-conversion default barrier without CoCos higher than conversion barrier.

2. $EQ^{BC}(V', V_b^{PC}) < 0$ for $V' > V_b^{PC}$:
   Limited liability violated for post-conversion default barrier

Theorem 2: Critical level for debt-induced collapse:

Assume $V_c$ is constant. There exists upper bounds on the amount of straight debt $\bar{P}_1$ and CoCos $\bar{P}_2$ such that the following holds:

- If either $P_D > \bar{P}_D$ or $P_C > \bar{P}_C$, then we have debt-induced collapse.
- If $0 \leq P_D < \bar{P}_D$ and $0 \leq P_C < \bar{P}_C$, then debt-induced collapse does not occur.
Critical Levels of Debt for Debt-Induced Collapse

- \(1/m\) = average debt maturity in years
- Total assets = 100
- Conversion barrier \(V_c = 75\)
- Number of shares at conversion \(n'\) s.t. face value of CoCos \(P_C\) equals market value of converted equity at \(V_t = V_c\)
Debt-Induced Collapse: Capital Ratio Trigger

Specification of the Conversion Barrier

\( V_c \) as a function of \( P_D \) and \( P_C \):

- In practice \( V_c \) is typically specified through the firms capital structure and asset value.
- Common equity (accounting notion): \( V_t - P_D - P_C \).
- Convert when \( \frac{V_t - P_D - P_C}{V_t} \leq \rho \), i.e.

\[
V_c = \frac{P_D + P_C}{1 - \rho}
\]

⇒ Similar result with common equity-based trigger as with constant barrier: excess amount of straight debt leads to debt-induced collapse.
Critical Levels of Debt for a Capital Ratio Trigger

Critical values of straight debt $P_D$, that lead to $V_b^{PC} > V_c$ and hence debt-induced collapse. We set $\rho = 0.05$ and $P_C = 5$. 
Too-Big-To-Fail (TBTF) Firms

- At default of a TBTF firm the government will take over its assets and its obligations to make payments to debt holders.
- Debt holders of TBTF firms have an implicit government guarantee on their debt contract, which makes their debt basically risk-free.

**Proposition: Optimal default barrier for TBTF firms**

The optimal default barrier $V_{b, TBTF}^{PC}$ of a post-conversion TBTF firm equals $V_{b}^{PC}$ with $\alpha = 0$, i.e. like a firm with no recovery at default.

$\Rightarrow$ Default risk is increasing faster in the amount of straight debt $P_{D}$ for a TBTF firm than for a normal firm.

$\Rightarrow$ Debt-induced collapse is a more serious concern for TBTF firms.
TBTF: Critical Levels of Debt for a Capital Ratio Trigger

Critical values of straight debt $P_D$ for a TBTF firm that lead to $V_{b,TBTF}^{PC} > V_c$ for a capital ratio trigger with $\rho = 0.05$ and $P_C = 5$. 
TBTF: Critical Levels of Debt for a Capital Ratio Trigger

Critical values of straight debt $P_D$ for a TBTF firm, that lead to $V_{b,TBTF}^{PC} > V_c$ for a capital ratio trigger with $c_C = r$ and $P_C = 5$. 
Incentive Effects

Incentives

- Set the conversion trigger sufficiently high (relative to total debt) \( \Rightarrow \) no debt-induced collapse, and the CoCos function as intended
- We can now look at incentive effects in the “good” regime
- Incentive effects depend on the interaction between debt maturity, CoCos and tail risk in the form of jumps

Simple Black-Scholes Merton model

- In a simple Black-Scholes Merton model: equity as a call, debt as a put on firm assets
  - Debt overhang (Myers 1977) because \( Delta < 1 \)
  - Asset substitution (Jensen and Meckling 1976) because \( Vega > 0 \)
Debt Overhang Costs

- Debt overhang: Equity holders are unwilling to invest in a firm nearing bankruptcy because most of the value of their investment goes to creditors.
- Debt overhang cost is always positive in a Black-Scholes-Merton-style model.
- With debt roll-over, the reduction in default risk benefits shareholders by reducing roll-over costs.
- What about CoCos?
Debt Overhang Cost

- Overhang cost = investment - change in equity value
- Conversion trigger = 75
- Without CoCos, overhang cost increases as asset value decreases
- Below the trigger, CoCos are irrelevant
- Good news: Overhang cost becomes very negative as asset value approaches the trigger and equity holders try to stave off conversion

⇒ This is an important incentive effect
Debt Overhang Cost: A Closer Look

- Removing tax deductibility of CoCo coupons reduces investment incentive (solid vs. dashed lines)
- Bad news: Removing jumps in asset value removes about half the investment incentive
- Removing tax benefits and jumps removes the incentives almost completely
Asset Substitution

After equity holders issue debt, they (may) have an incentive to increase the riskiness of the assets

- As in a Merton model, equity holders capture the upside
  ⇒ This encourages more risk

- Riskier assets increase debt rollover costs
  ⇒ Debt is issued at market value but repaid at face value, so risk reduces dividends
  ⇒ This argues for less risk, particularly with shorter-maturity debt

- With CoCos, conversion leads to (partial) loss of tax shield
  ⇒ This argues for less risk

- Shareholders prefer conversion at a lower asset level
  ⇒ This argues for less diffusion risk and more jump risk
CoCos give incentives to equity holders to take less diffusive risk.

Without CoCos equity holders have positive risk-taking incentives.
Sensitivity of equity value to diffusive volatility and jump risk in assets with maturity $\frac{1}{m} = 25$ years.
Asset Substitution: Short Maturity

Sensitivity of equity value to diffusive volatility and jump risk in assets with maturity $\frac{1}{m} = 4$ years.
Calibration: Data

Data

- Time 2004-2011: Years before and during the financial crisis
- 17 bank holding companies that underwent the Supervisory Capital Assessment Program (SCAP) in 2009. (the largest 17 at the time)
- Accounting data from 10-Q/10-K S.E.C. filings (quarterly)
- Equity price data from CRSP (weekly)
- Debt data from Fixed Income Securities and TRACE databases

Calibration idea

- For discrete set \((\lambda, \eta, \sigma)\) we calculate model-implied asset value
- Identify jumps as returns larger than \(3.3\sigma\)
- Estimate \((\lambda, \eta, \sigma)\) by matching implied and observed debt prices
- Set conversion trigger to avoid debt-induced collapse
Calibration: Illustration

Calibration

SunTrust Banks, Inc. – assets & market capitalization

Calibration results for Sun Trust: Model-implied asset value
Calibration: Illustration

Calibration

SunTrust Banks, Inc. – default boundaries

Calibration results for Sun Trust: Optimal default barrier
Calibration results for Sun Trust: Conversion time
Calibration results for Sun Trust: Debt overhang costs
Summary and Concluding Remarks

- Interactions between endogenous default, debt rollover, and jumps in asset value have significant impact on the functioning of CoCos

- Main Observations
  - CoCos reduce debt overhang costs near conversion
  - Reduce appetite for asset volatility, but can increase appeal of tail risk
  - Equity holders capture some of the benefit of reduced bankruptcy costs $\Rightarrow$ often positive incentive to issue CoCos
  - Calibration to bank data suggests that CoCos would have had positive effects through the crisis

- Policy implications
  - Trigger needs to be high enough to avoid debt-induced collapse
  - Short-term debt and TBTF makes debt-induced collapse more likely
Overview of Other Research Projects

Further Research Projects

Large dimensional factor modeling based on high-frequency observations

- Statistical inferential theory
  - Asymptotic distribution for factors and loadings
  - Estimation of the number of factors
  - Separation of continuous and jump factors

⇒ Combination of high-frequency econometrics, principal component analysis and random matrix theory

- Empirical implementation
  - Data set: S&P500 firms, 10 years, 5min prices
  - Identification of four highly persistent continuous factors

Other projects

- Efficient large dimensional factor analysis
- Arbitrage pricing theory for general processes
- Management compensation
Thank you!
Straight Debt (Chen and Kou (2009))

## Unit bond

Value of a bond issued at time 0 with face value 1 and maturity \( t \):

\[
b(V, V_b, t) = \mathbb{E}^Q \left[ \int_{0}^{t \wedge \tau_b} c_D e^{-rs} ds \right] + \mathbb{E}^Q \left[ e^{-rt} 1_{\{t < \tau_b\}} \right] + \frac{\alpha}{P_D} \mathbb{E}^Q \left[ V(\tau) e^{-r\tau_D} 1_{\{\tau_b \leq t\}} \right].
\]

- default time: \( \tau_b = \inf\{t \in (0, \infty) : V_t \leq V_b \} \)
- \( c_D = \) constant coupon rate
- \( P_D = \) total face value of straight debt
- \( 1 - \alpha = \) bankruptcy loss
- expectation under the martingale measure \( Q \).
Straight Bonds

Rolling debt structure: (Leland (94), ChenKou (09))

- firm issues new debt in the amount $p_D dt$ in $(t, t + dt)$.
- maturity profile $me^{-st}$ (i.e. there is a portion $me^{-ms} pds$ of $p_D dt$ due in the interval $(t + s, t + s + ds)$)
- average maturity of debt $\int_0^\infty t me^{-mt} dt = \frac{1}{m}$

$\Rightarrow$ constant face value of debt: $P_D = p_D \int_0^\infty e^{-mt} dt = \frac{PD}{m}$

Total debt

Total value of all outstanding debt

$$B(V, V_B) = P_D \int_0^\infty me^{-mt} b(V, V_B, t) dt$$
Equity Value for Post-Conversion Firm (only straight debt)

Total value of a post-conversion firm $F_{PC}$ (only straight debt)

$$F_{PC}(V, V_b) = \sqrt{V} + TB_D(V, V_b) - BCOST(V, V_b)$$

- tax benefits:
  $$TB_D = P_D \cdot E^Q \left[ \int_0^{\tau_b} \kappa c_D e^{-rt} dt \right]$$
- $\kappa$ corporate tax rate
- bankruptcy costs:
  $$BCOST(V, V_b) = E^Q [(1 - \alpha)V_{\tau_b} e^{-r\tau_b}]$$

Equity for a Post-Conversion Firm (only straight debt)

Value of the firm’s equity with only straight debt:

$$EQ_{PC}(V, V_b) = F_{PC}(V, V_b) - B(V, V_b)$$
Too-Big-To-Fail (TBTF) Firms

- At default of a TBTF firm the government will take over its assets and its obligations to make payments to debt holders.
- Debt holders of TBTF firms have an implicit government guarantee on their debt contract, which makes their debt basically risk-free.

Straight debt value of TBTF firms

\[
B_{TBTF} = \int_0^\infty P_D \left( \int_0^t c_D e^{-rs} ds + e^{-rt} \right) me^{-mt}(t) dt = \frac{c_D P_D + mP_D}{m + r}.
\]

Value of the government subsidy

\[
SUB_{TBTF}(V, V_b) = \frac{c_D P_D + mP_D}{m + r} \mathbb{E}^Q \left[ e^{-(m+r)\tau_b} \right] - \mathbb{E}^Q \left[ V_{\tau_B} e^{-r\tau_b} \right].
\]
Too-Big-To-Fail (TBTF) Firms

Total value and equity value of TBTF firms with only straight debt

\[ F_{TBTF}^{PC}(V, V_b) = V + TB_D(V, V_b) + SUB_{TBTF}(V, V_b) \]
\[ EQ_{TBTF}^{PC}(V, V_b) = F_{TBTF}^{PC}(V, V_b) - B_{TBTF}(V, V_b) \]

Analogously \( EQ_{TBTF}^{BC}, D_{TBTF}, \ldots \)

Proposition: Optimal default barrier for TBTF firms

The optimal default barrier \( V_{b, TBTF}^{PC} \) of a post-conversion TBTF firm equals \( V_{b}^{PC} \) with \( \alpha = 0 \), i.e. like a firm with no recovery at default.

\[ \Rightarrow \] Default risk is increasing faster in the amount of straight debt \( P_D \) for a TBTF firm than for a normal firm.

\[ \Rightarrow \] Debt-induced collapse is a more serious concern for TBTF firms.
### Base Case Parameters for Simulations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>initial asset value ( V_0 )</td>
<td>100</td>
</tr>
<tr>
<td>risk free rate ( r )</td>
<td>6%</td>
</tr>
<tr>
<td>volatility ( \sigma )</td>
<td>8%</td>
</tr>
<tr>
<td>payout rate ( \delta )</td>
<td>1%</td>
</tr>
<tr>
<td>tax rate ( \kappa )</td>
<td>35%</td>
</tr>
<tr>
<td>jump intensity ( \lambda_f )</td>
<td>0.3</td>
</tr>
<tr>
<td>firm specific jump exponent ( \eta )</td>
<td>4</td>
</tr>
<tr>
<td>coupon rates ( (c_1, c_2) )</td>
<td>( (r + 3%, r + 3%) )</td>
</tr>
<tr>
<td>bankruptcy loss ( (1 - \alpha) )</td>
<td>50%</td>
</tr>
</tbody>
</table>

Base case parameters. Asset returns have a total volatility (combining jumps and diffusion) of 21%. On average every 3 years a jump costs the firm a fifth of its value. The number of shares \( \Delta \) issued at conversion is set such that the market value of shares delivered is the same as the face value of the converted debt if conversion happens at exactly \( V_c \).
### Parameters for Extended Model used in Simulations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>initial asset value</td>
<td>$V_0$</td>
</tr>
<tr>
<td>debt principal</td>
<td>$(P_{1a}, P_{1b}, P_{1c})$</td>
</tr>
<tr>
<td>risk free rate</td>
<td>$r$</td>
</tr>
<tr>
<td>volatility</td>
<td>$\sigma$</td>
</tr>
<tr>
<td>payout rate</td>
<td>$\delta$</td>
</tr>
<tr>
<td>tax rate</td>
<td>$\kappa$</td>
</tr>
<tr>
<td>firm specific jump intensity</td>
<td>$\lambda_f$</td>
</tr>
<tr>
<td>market jump intensity</td>
<td>$\lambda_m$</td>
</tr>
<tr>
<td>firm specific jump exponent</td>
<td>$\eta_f$</td>
</tr>
<tr>
<td>market jump exponent</td>
<td>$\eta_m$</td>
</tr>
<tr>
<td>coupon rates</td>
<td>$(c_{1a}, c_{1b}, c_{1c}, c_2)$</td>
</tr>
<tr>
<td>deposits insurance premium rate</td>
<td>$\varphi$</td>
</tr>
<tr>
<td>contingent capital principal</td>
<td>$P_2$</td>
</tr>
<tr>
<td>maturity profile exponent – base case</td>
<td>$(m_{1a}, m_{1b}, m_{1c}, m_2)$</td>
</tr>
<tr>
<td>maturity profile exponent – long maturity</td>
<td>$(m_{1a}, m_{1b}, m_{1c}, m_2)$</td>
</tr>
<tr>
<td>conversion trigger</td>
<td>$V_c$</td>
</tr>
<tr>
<td>conversion loss (if applied)</td>
<td></td>
</tr>
</tbody>
</table>

Parameters for extended model. Asset returns have a total volatility (combining jumps and diffusion) of 20.6\% and overall drift rate of 3.3\%. In the base case, the number of shares $\Delta$ issued at conversion is set such that if conversion happens at exactly $V_c$, the market value of shares delivered is the same as the face value of the converted debt.
## Calibrated Parameter Values

<table>
<thead>
<tr>
<th>Bank Holding Company</th>
<th>Parameters</th>
<th>Conversion Date</th>
<th>50%</th>
<th>75%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bank of America Corp</td>
<td>λ=0.1 η=5  σ=4.1%</td>
<td>JAN-09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>JPMorgan Chase &amp; Co.</td>
<td>λ=0.1 η=8  σ=4.4%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Citigroup Inc.</td>
<td>λ=0.1 η=9  σ=3.9%</td>
<td>NOV-08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wells Fargo &amp; Company</td>
<td>λ=0.1 η=5  σ=4.7%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goldman Sachs Group, Inc.</td>
<td>λ=0.1 η=5  σ=3.8%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morgan Stanley</td>
<td>λ=0.1 η=8  σ=4.2%</td>
<td>SEP-08 DEC-08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PNC Financial Services</td>
<td>λ=0.3 η=8  σ=7.0%</td>
<td>NOV-08 JAN-09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>U.S. Bancorp</td>
<td>λ=0.3 η=5  σ=5.5%</td>
<td>JAN-09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bank of New York Mellon Corp.</td>
<td>λ=0.3 η=6  σ=7.3%</td>
<td>OCT-08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SunTrust Banks, Inc.</td>
<td>λ=0.3 η=9  σ=4.1%</td>
<td>APR-08 JAN-09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital One Financial Corp.</td>
<td>λ=0.3 η=7  σ=7.9%</td>
<td>JUN-08 JAN-09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BB&amp;T Corporation</td>
<td>λ=0.3 η=6  σ=5.3%</td>
<td>JUN-08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regions Financial Corporation</td>
<td>λ=0.3 η=8  σ=4.7%</td>
<td>JUN-08 JAN-09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>State Street Corporation</td>
<td>λ=0.3 η=5  σ=7.4%</td>
<td>OCT-08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>American Express Company</td>
<td>λ=0.3 η=8  σ=8.6%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fifth Third Bancorp</td>
<td>λ=0.3 η=5  σ=6.3%</td>
<td>JAN-08 JUN-08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KeyCorp</td>
<td>λ=0.3 η=8  σ=4.2%</td>
<td>NOV-07 NOV-08</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The table shows the calibrated parameter values ($\lambda, \eta, \sigma$) for each bank holding company. The last two columns show the months in which CoCo conversion would have been triggered, according to the calibration, assuming CoCos made up 10% of debt. The 50% and 75% dilution ratios correspond to higher and lower triggers, respectively.
## Estimated Loss Absorption of CoCos

<table>
<thead>
<tr>
<th></th>
<th>Jan-2006</th>
<th>Jan-2007</th>
<th>Jan-2008</th>
<th>Jan-2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bank of America Corp</td>
<td>1.47 7%</td>
<td>1.43 8%</td>
<td>1.63 5%</td>
<td>1.54 3%</td>
</tr>
<tr>
<td>JPMorgan Chase &amp; Co.</td>
<td>1.29 6%</td>
<td>1.29 6%</td>
<td>1.49 5%</td>
<td>1.50 5%</td>
</tr>
<tr>
<td>Citigroup Inc.</td>
<td>1.34 7%</td>
<td>1.32 6%</td>
<td>1.42 4%</td>
<td>- 2%</td>
</tr>
<tr>
<td>Wells Fargo &amp; Company</td>
<td>1.11 19%</td>
<td>1.06 22%</td>
<td>1.44 9%</td>
<td>1.60 5%</td>
</tr>
<tr>
<td>Goldman Sachs Group, Inc.</td>
<td>1.35 4%</td>
<td>1.41 5%</td>
<td>1.52 4%</td>
<td>- 4%</td>
</tr>
<tr>
<td>Morgan Stanley</td>
<td>1.43 4%</td>
<td>1.38 4%</td>
<td>1.50 5%</td>
<td>- 5%</td>
</tr>
<tr>
<td>PNC Financial Services</td>
<td>1.17 19%</td>
<td>1.11 21%</td>
<td>1.29 14%</td>
<td>- 8%</td>
</tr>
<tr>
<td>U.S. Bancorp</td>
<td>0.95 32%</td>
<td>0.98 32%</td>
<td>1.11 24%</td>
<td>1.17 18%</td>
</tr>
<tr>
<td>Bank of New York Mellon</td>
<td>1.15 24%</td>
<td>1.06 28%</td>
<td>1.04 28%</td>
<td>0.80 17%</td>
</tr>
<tr>
<td>SunTrust Banks, Inc.</td>
<td>0.91 21%</td>
<td>0.87 22%</td>
<td>0.91 16%</td>
<td>- 8%</td>
</tr>
<tr>
<td>Capital One Financial Corp.</td>
<td>0.93 29%</td>
<td>0.92 26%</td>
<td>0.97 16%</td>
<td>- 12%</td>
</tr>
<tr>
<td>BB&amp;T Corporation</td>
<td>1.03 25%</td>
<td>1.03 23%</td>
<td>0.97 14%</td>
<td>- 9%</td>
</tr>
<tr>
<td>Regions Financial Corp.</td>
<td>0.90 24%</td>
<td>0.89 19%</td>
<td>0.87 12%</td>
<td>- 4%</td>
</tr>
<tr>
<td>State Street Corporation</td>
<td>1.33 18%</td>
<td>1.25 20%</td>
<td>1.07 24%</td>
<td>- 11%</td>
</tr>
<tr>
<td>American Express Company</td>
<td>1.15 38%</td>
<td>1.13 36%</td>
<td>1.26 28%</td>
<td>1.50 18%</td>
</tr>
<tr>
<td>Fifth Third Bancorp</td>
<td>0.89 26%</td>
<td>0.77 31%</td>
<td>- 17%</td>
<td>- 6%</td>
</tr>
<tr>
<td>KeyCorp</td>
<td>1.11 17%</td>
<td>1.01 20%</td>
<td>- 10%</td>
<td>- 5%</td>
</tr>
<tr>
<td><strong>mean</strong></td>
<td>1.15 18.81%</td>
<td>1.11 19.23%</td>
<td>1.23 13.73%</td>
<td>1.35 8.15%</td>
</tr>
<tr>
<td><strong>median</strong></td>
<td>1.15 19.32%</td>
<td>1.06 20.52%</td>
<td>1.26 13.80%</td>
<td>1.50 5.81%</td>
</tr>
</tbody>
</table>

Under each date the left column shows the ratio of the increase in loss absorption (the change in the default boundary after CoCo issuance) to CoCo size (as measured by market value). The right column is the distance to default (without CoCos) as a percentage of asset level. The dilution ratio is 50%.
## Estimated Debt Overhang Costs

<table>
<thead>
<tr>
<th>Bank</th>
<th>Feb-2008</th>
<th>Apr-2008</th>
<th>Aug-2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bank of America Corp</td>
<td>-29%</td>
<td>-26%</td>
<td>-28%</td>
</tr>
<tr>
<td>JPMorgan Chase &amp; Co.</td>
<td>-75%</td>
<td>-43%</td>
<td>-93%</td>
</tr>
<tr>
<td>Citigroup Inc.</td>
<td>-42%</td>
<td>-24%</td>
<td>-54%</td>
</tr>
<tr>
<td>Wells Fargo &amp; Company</td>
<td>-35%</td>
<td>-33%</td>
<td>-33%</td>
</tr>
<tr>
<td>Goldman Sachs Group</td>
<td>-51%</td>
<td>-33%</td>
<td>-53%</td>
</tr>
<tr>
<td>Morgan Stanley</td>
<td>21%</td>
<td>21%</td>
<td>-20%</td>
</tr>
<tr>
<td>PNC Financial Services</td>
<td>-11%</td>
<td>-7%</td>
<td>-10%</td>
</tr>
<tr>
<td>U.S. Bancorp</td>
<td>4%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>Bank of New York Mellon</td>
<td>-3%</td>
<td>-1%</td>
<td>6%</td>
</tr>
<tr>
<td>SunTrust Banks, Inc.</td>
<td>-2%</td>
<td>5%</td>
<td>9%</td>
</tr>
<tr>
<td>Capital One Financial</td>
<td>-4%</td>
<td>5%</td>
<td>6%</td>
</tr>
<tr>
<td>BB&amp;T Corporation</td>
<td>2%</td>
<td>4%</td>
<td>6%</td>
</tr>
<tr>
<td>Regions Financial Corp.</td>
<td>-7%</td>
<td>-8%</td>
<td>-9%</td>
</tr>
<tr>
<td>State Street Corporation</td>
<td>2%</td>
<td>5%</td>
<td>6%</td>
</tr>
<tr>
<td>American Express Co.</td>
<td>-12%</td>
<td>-7%</td>
<td>-10%</td>
</tr>
<tr>
<td>Fifth Third Bancorp</td>
<td>12%</td>
<td>17%</td>
<td>19%</td>
</tr>
<tr>
<td>KeyCorp</td>
<td>-6%</td>
<td>-1%</td>
<td>5%</td>
</tr>
</tbody>
</table>

Under each date, the first column is the debt overhang cost as a percentage of the increase in assets with no CoCos. The second column quotes the same value when 10% of debt is replaced with CoCos and CoCo investors receive 50% of equity at conversion. The third column is the distance to conversion as the percentage of assets. The dates correspond to one month before announcement and final approval of acquisition of Bear Stearns by JPMorgan and one month before the Lehman bankruptcy. A table entry is blank if the corresponding date is later than the CoCo conversion date for the corresponding bank.