

# Understanding Contingent Capital

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# Understanding Contingent Capital

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**Abstract.** This paper is a response to the Casualty Actuarial Society's request for proposals on "Contingent Capital." In light of the recent financial crisis, contingent capital, a type of hybrid security, is seen as an innovative way of recapitalization given the occurrence of a specified event, such as the capital adequacy ratio falling below the threshold. Although it has gained prominence among regulators, there are some doubts from market participants. The effectiveness of this automatic bail-in hybrid security is still too early to tell, given the limited market experience and unclearness of the impact on the share price when the conversion is triggered. The goal of this research is to explore the key features of contingent capital, its market, the appropriate pricing and valuation tools, and its application in insurance industry. It is hoped that the research will increase our understanding of contingent capital and facilitate the assessment of its value and risk.

**Motivation.** As a new alternative of raising capital automatically under stressed situations, contingent capital is expected to have more weight on insurers' balance sheets in the future. It is important for actuaries to understand contingent capital and have the necessary tools to assess its risk.

**Method.** This paper provides an overview of the contingent capital market, its features, and its potential impact. It also discusses the pricing and valuation models for certain contingent capital instruments. A case study is included to illustrate the quantitative analysis for a contingent capital instrument.

**Results.** A spreadsheet model is built and used in the case study. It is capable of pricing and valuing certain types of contingent capital. Quantitative risk analysis and model calibration function is also included. It could serve as good education materials to understand the role of contingent capital, quantify its risk, and assess its effectiveness of absorbing loss.

**Conclusions.** Contingent capital is a promising candidate to improve the capital position of the financial industry with a smaller cost than additional rights issuance. However, further analysis and testing are needed to find out the appropriate design and better understand its potential impact and related stakeholder behavior. There is still a journey to go before the success.

**Availability.** The spreadsheet "CONTINGENT CAPITAL QA TOOL" that illustrates the quantitative analysis of contingent capital is available, together with the report.

**Keywords.** Capital management, contingent capital, CoCo bond, systemic risk

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**Table of Contents**

UNDERSTANDING CONTINGENT CAPITAL..... 1

EXECUTIVE SUMMARY..... 4

1. INTRODUCTION..... 5

    1.1 Research Context..... 5

    1.2 Objective..... 5

    1.3 Outline ..... 5

2. CONTINGENT CAPITAL MARKET..... 6

    2.1 Market Overview ..... 6

    2.2 Do We Need Contingent Capital? ..... 7

    2.3 Designs of Contingent Capital ..... 8

    2.4 Stakeholder Analysis ..... 9

    2.5 Some Doubts about Contingent Capital..... 13

3. KEY FEATURES..... 15

    3.1 Trigger Event: Rule Based or Discretionary..... 15

    3.2 Trigger Event: Institution Level and/or Industry Level..... 16

    3.3 Trigger Event: Based on Book Value or Market Value ..... 17

    3.4 Conversion Price ..... 18

    3.5 Market Manipulation..... 19

    3.6 Multiple Equilibria..... 20

    3.7 Proposals..... 22

    3.8 Post Conversion ..... 24

    3.9 Contingent Capital versus Other Risk Transfer Instruments ..... 25

4. EFFECTIVENESS AND POTENTIAL IMPACT ..... 28

    4.1 The Impact on Systemic Risk ..... 28

    4.2 Dilution of Shareholder Value..... 29

    4.3 Capital Admittance and Accounting Treatment ..... 29

    4.4 Tax Deductibility ..... 31

    4.5 Disclosure Requirement ..... 32

    4.6 Counterparty Risk Assessment..... 32

5. PRICING, VALUATION, AND RISK ASSESSMENT ..... 33

    5.1 Pricing Models ..... 33

    5.2 Valuation Models and Assumption Setting ..... 41

    5.3 Risk Assessment ..... 44

6. CASE STUDY ..... 46

    6.1 Pricing ..... 47

    6.2 Valuation..... 54

    6.3 Risk Assessment ..... 55

7. CONCLUSION ..... 59

    Acknowledgment ..... 59

    Supplementary Material ..... 59

APPENDIX A. QUICK GUIDE FOR CONTINGENT CAPITAL QA TOOL ..... 60

APPENDIX B. MORE FORMULAS USED IN THE CASE STUDY ..... 60

8. REFERENCES ..... 65

    Biography of the Author..... 68

## **EXECUTIVE SUMMARY**

The financial industry was quite successful in financial instruments innovations to meet the needs of investors. The wide development of the financial derivative market has been providing hedging tools to transfer financial risks for institutional investors. The insurance industry provides risk transfer as well, built on pooling the individual insurance risks together, and provides protection at a reasonable and affordable price. Using reinsurance and alternative risk transfer instruments that are normally linked with catastrophe risk, risk mitigation activities are prevalent in insurance industry.

However, they may not be sufficient to survive a financial crisis. Firms failed for different reasons but clearly they held insufficient capital for the risks they took. A huge amount of money was paid by taxpayers merely to keep some systematically important firms alive. The cost was supposed to be borne by the investors, however. The regulators and the financial industry are now taking steps to adopt a more stringent capital rule. Contingent capital caught a lot of attention as a candidate to strengthen the capital position, reduce the cost of financial crisis borne by the taxpayers, and limit the increasing cost of capital due to more stringent capital requirements. Generally speaking, contingent capital provides automatic recapitalization by converting the debt instrument to equity when the issuer is in trouble. The trigger of the conversion is based on a pre-specified condition, such as equity price dropping below a certain amount or regulatory capital ratio dropping below a certain level. This innovation links the automatic bail-in with the capital position of the company, covering a much broader scope of risks than ever before.

Several companies issued contingent capital instruments, either as a solution for the stressed financial condition or as an action to boost the capital buffer for future adverse events. There are many proposals of contingent capital design from the academic community, as well. The prevalence of different opinions of the appropriate trigger event for conversion implies the complexity of contingent capital and the immaturity of the market. There are concerns about the stakeholders' rational behaviors that may push the firm down to an even worse situation. This is exactly opposite to what the contingent capital is designed for. Other concerns include the softening of debt's disciplining power and its effectiveness. There is a lot to explore and test in the market before contingent capital becomes a widely accepted instrument for prudent capital management and risk management.

This paper introduces the background of contingent capital, its key features, its potential impact, and the models for pricing, valuation, and risk assessment. It explains the reasons for issuing contingent capital as well as the major concerns about it. It also includes a case study illustrating the pricing, valuation, and quantitative risk analysis of a sample contingent capital instrument.

## **1. INTRODUCTION**

This paper is a response to the request for proposals on contingent capital by the Committee on Valuation, Finance, and Investments (VFIC) of the Casualty Actuarial Society (CAS).

### **1.1 Research Context**

The insurance industry has been utilizing non-traditional capital instruments to transfer risks for a long time. Some of them help insurers absorb losses and retain their capital in adverse events. For example, catastrophe bonds or catastrophe equity put arrangements protect the insurers from catastrophe losses. Those instruments are normally related to insurance risk, such as natural disasters, mortality, and longevity.

In the recent financial crisis, systemic risk caught a lot of attention. Much discussion happened on how to prevent or mitigate systemic risk. Regulators are also changing their ways to regulate those too-big-to-fail, or systemically important financial institutions. Contingent capital, an innovative type of automatic bail-in hybrid security, is considered a candidate for providing capital at a predetermined cost in stressed situations and for mitigating systemic risk. Contingent capital instruments are similar to non-traditional capital instruments used by insurance companies, except that the trigger is based on financial conditions instead of insurance risk. Different designs of contingent capital have been proposed and some of them are implemented. Although their effectiveness is still too early to tell, it is important for us to understand them and be equipped with knowledge and analytical tools for valuation and risk assessment.

### **1.2 Objective**

The objective of this paper is to explore the key features and characteristics of contingent capital instruments, their effectiveness in risk transfer, and the pricing and valuation tools for them. A quantitative illustrative tool is made available for contingent capital evaluation and risk assessment. It is hoped that the tool will aid the actuarial community in understanding contingent capital from the perspective of risk transfer and capital management.

### **1.3 Outline**

The remainder of the paper proceeds as follows. Section 2 gives an overview of the contingent capital market. Section 3 discusses the key features of contingent capital instruments. Section 4 presents their impact and effectiveness in risk mitigation and capital management. Section 5 explores modern finance theory and quantitative models used in pricing, valuation, and risk reward analysis. It is followed by a case study of evaluating a sample contingent convertible bond in Section 6. Section

7 concludes the paper.

## **2. CONTINGENT CAPITAL MARKET**

Contingent capital instruments, also known as contingent convertible bonds (CoCo bonds), contingent surplus notes, or enhanced capital notes, provide a mechanism that automatically convert the instruments to equity upon the occurrence of a specified trigger event. These instruments began to attract attention and gain popularity during the 2008 financial crisis. Before that, insurance companies protected themselves from capital deficiency under stressed situations by reinsurance arrangements, hedging programs, and capital raising. Those seem effective when systemic risk is mild in the financial system. However, the recent financial crisis told us that when systemic risk is prevalent, the cost of raising capital may be unaffordable. Much higher liquidity risk and counterparty risk might still put the company in a weak solvency position. Contagion impact is material and the market and regulators have been looking for capital instruments that provide better insulation. Contingent capital appears to be the most promising solution, although doubts about it are not rare.

### **2.1 Market Overview**

The insurance industry has been utilizing contingent capital instruments for around two decades. Catastrophe equity puts and contingent surplus notes are the most common types. Catastrophe equity puts<sup>1</sup> give the insurer the right to sell stocks at a fixed price in case a specified trigger event happens. Contingent surplus notes<sup>2</sup> give the insurer the right to issue surplus notes in exchange for liquid assets upon the occurrence of a predefined trigger event. The size of the transaction ranges from a few million dollars to around half a billion dollars. However, the trigger events, or, in other words, the risks from which the companies have been protected are normally catastrophe risk related. The term of the protection is also relatively short.

Contingent capital with a trigger event based on regulatory solvency ratio instead of insurance risk caught public attention in Lloyds Banking Group's exchange offer announced in November 2009. It intended to exchange certain existing securities<sup>3</sup> for enhanced capital notes or rights issue.<sup>4</sup>

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<sup>1</sup> CEIOPS, "Insurance Linked Securities," 5.

<sup>2</sup> CEIOPS, "Insurance Linked Securities," 5.

<sup>3</sup> Existing securities subject to exchange offer comprised of "Upper Tier 2 securities in an aggregate principal amount of £2.52 billion, innovative Tier 1 securities in an aggregate principal amount of £7.68 billion and preference shares (or equivalents) with an aggregate liquidation preference of £4.09 billion", Lloyds Banking Group, "Exchange Offer," 2.

Casualty Actuarial Society *E-Forum*, 2013 Spring-Volume 2

## *Understanding Contingent Capital*

The enhanced capital notes (ECNs) will be converted to ordinary shares if the core tier 1 capital ratio falls below 5%. Not only the unprecedented size for contingent capital issuance but also the government's big stake in the company made this transaction very special. Contingent capital is considered more favorable than old-fashioned hybrid securities such as convertible bonds and preferred shares under stressed scenarios. These traditional hybrid securities are not as good as contingent capital instruments in loss absorbing.

In addition to conversion to equity if the trigger event happens, some other arrangements were also tried. In 2010, Rabobank issued a €1.25 billion 10-year Senior Contingent Note. Once the capital ratio falls below 7%, the face amount will be written down to 25% and paid back to investors. Liability value will be reduced if the trigger event happens, which effectively is a capital injection. This is different from contingent convertible bonds, where only the debt/equity ratio changes but the amount of capital remains the same if conversion is made at market price.

The €500 million deal of contingent convertible bonds between Allianz and Nippon Life in mid-2011 demonstrated the high interest of the insurance industry in using contingent capital to improve its capital position and reduce its risk exposure.

Not only banks and insurance companies but other financial institutes have used contingent capital. In the merger of Yorkshire Building Society and Chelsea Building Society in 2009, £200 million subordinated securities of Chelsea Building Society were planned in exchange for contingent convertible bonds. Once the core tier 1 capital ratio falls below 5%, they will automatically be converted into equity.<sup>5</sup>

## **2.2 Do We Need Contingent Capital?**

Before diving into the details about contingent capitals, it is worth understanding the reasons for bringing contingent capital into the capital structure. From the regulators' perspective, it is hoped that contingent capital could solve the too-big-to-fail problem and reduce the loss paid by taxpayers instead of the investors. Compared to issuing new stocks, investors want to take advantage of the debt-like feature of the contingent capital: tax deductibility before the conversion and upfront and fixed recapitalization cost at conversion.

As seen in the financial crisis since 2008, many too-big-to-fail companies needed government

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<sup>4</sup>The package was supposed to "(i) generate at least £7.5 billion in core tier one and/or nominal value of contingent core tier 1 capital through the Exchange Offer and/or related arrangements; and (ii) raise £13.5 billion (£13 billion net of expenses) by way of a Rights Issue, Lloyds Banking Group, "Exchange Offer," 1.

<sup>5</sup> A list of contingent capital instruments issued in the past few years is given in Goldman Sachs, "Contingent Capital Possibilities," 17-18.

## *Understanding Contingent Capital*

bailout merely to survive. The bad outcomes of writing riskier business than what the available capital could support were borne by the taxpayers, not the investors who made the business decision. Higher capital requirement could certainly reduce the chance of default. However, as Bolton and Samama (2011) pointed out, the foreseen increased capital requirement for the banking industry according to Basel III may make it more difficult to earn the required return on equity (RoE) if the increased capital requirement needs to be met by the issuance of stocks. In addition, a sudden shift to a much more stringent capital requirement might also result in a credit crisis as the banks hold much less than the required capital as a buffer than previously required or have to raise capital to meet the capital requirement. Contingent capital seems to be a promising solution.

- (1) As a debt instrument before conversion, it limits the increase in weighted average cost of capital (WACC). It will not cause the concern of higher required RoE in normal circumstances, which happens when financing with common equity.
- (2) The tax deductibility of the debt instruments is also an argument for investors to utilize contingent capital in their financing. The disciplining power of creditors might also be preserved before conversion by maintaining the same leverage level as before.
- (3) Firms normally try to sell troublesome assets and get rid of troublesome liabilities instead of issuing new stocks due to its high cost. Issuing contingent capital in good time fixes the recapitalization cost at a reasonable level in a future distressed situation. Apparently it is a cheaper way than raising capital in bad economic times.
- (4) It can reduce the default probability without government bailout. Upon conversion, the capital base of the company will be increased so that it will have a stronger capital position than that before the conversion. The loss will be borne by the investors of contingent capital instead of the taxpayers. Therefore, it helps fulfill the goal of applying more stringent capital rules to too-big-to-fail firms. Bankruptcy and government bailout are very costly. Contingent capital can lower the chance of going through those expensive processes.

### **2.3 Designs of Contingent Capital**

Despite the skepticism, there is a high and increasing interest in contingent capital instruments. Many designs of contingent capital have been proposed in trying to address the issues mentioned above. The key differences between possible designs so far concern the trigger event and the method of loss absorbency.

*Scope of the trigger event.* The trigger event can be based on the issuer's financial condition or on an industry-wide indicator. Industry-wide indicators, such as an aggregated market loss index or



## *Understanding Contingent Capital*

financial industry loss index, may be more suitable for mitigating systemic risk. However, it is hard to implement in an objective way and may convey an adverse message to the market.

*Type of the trigger event.* The trigger event can be related to the stock price, regulatory capital adequacy ratio such as core tier 1 ratio, credit condition such as credit default swap (CDS) spread, or even at the regulator's discretion. Double trigger contingent capital has also been proposed.

*Level of the trigger point.* Going-concern contingent capital normally has a high threshold, while gone-concern contingent capital has a low threshold, such as the point of non-viability. Besides the conversion of contingent capital, regulator's intervention is normally expected at the point of non-viability.

*The method of loss absorbency.* After the trigger event happens, contingent capital instruments will be converted to common equity, or have a write down of face amount and therefore liability. The impact is considered to be different. Write-down liability is similar to a capital injection, while conversion to equity is considered as capital restructure.

Details of those proposals and their different impacts will be explored in Section 3 and Section 4.

## **2.4 Stakeholder Analysis**

Regulators have shown great interest in utilizing contingent capital to absorb losses under stressed conditions because it is expected to reduce the need of a government bailout and therefore taxpayers' support. After a sizable market is developed for contingent capital, the value of issuers, buyers, and existing stockholders and their roles in corporate governance will also be impacted. Rating agencies have also considered the rating methodology for this new type of hybrid securities and to what extent it can boost the issuer's financial strength.

### **2.4.1 Regulators**

Regulators have been busy improving the capital adequacy rules to address the issues emerging from the financial crisis since 2008. In addition to a higher level of capital requirement, the qualification standard of hybrid securities to meet the additional capital requirement is also one of the major focuses. Although the future success of contingent capital is uncertain, it is very likely that contingent capital will become a part of the capital structure to meet regulators' requirements.

- (1) In October 2010, Financial Stability Board (FSB) recommended that global systematically important financial institutions (SIFIs) should have higher loss absorbency.<sup>6</sup> One of the candidates that could be used to meet the stringent requirement is contingent capital which

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<sup>6</sup> FSB, "Reducing the moral hazard," 3.

## *Understanding Contingent Capital*

absorbs loss at the point of non-viability. It was later endorsed by the G20.

- (2) Basel Committee on Banking Supervision (BCBS) released a rule about the additional loss absorbency requirement for global systematically important banks (GSIB) in late 2011. BCBS has considered different forms of contingent capital and decided the minimum requirements for going-concern contingent capital in order to meet additional requirements for GSIB. Contingent capital will have to be converted to Common Equity Tier 1 when the Common Equity Tier 1 falls below at least 7% of risk adjusted assets, which is a high threshold. It is also required to have a cap on the new shares and the full authorization of the issuers for an immediate conversion. The rule is expected to be phased in between 2016 and 2018 and become effective in 2019.
- (3) The European Union amended its capital requirements directive (CRD) in 2009, known as CRD II, which highlighted the importance role of hybrid capital instruments in capital management. Instruments that absorb losses on a going-concern basis and that must be converted to core tier 1 capital are regarded as equity capital. In 2010, a consultation paper (CRD IV) that includes possible further changes was issued. It states that the European Commission will consider the potential need for all non-core tier 1 instruments to have a mandatory principal write-down or conversion feature, the potential triggers for conversion, and alternative mechanisms and triggers of contingent capital.<sup>7</sup>
- (4) U.S. regulators are also interested in the idea of using contingent capital. As one of the provisions in the Dodd-Frank Wall Street Reform and Consumer Protection Act, Federal Reserve may establish heightened prudential standards for contingent capital requirement. It *"authorizes the Board to require each Board-supervised nonbank financial company and bank holding companies with total consolidated assets of \$50 billion or more to maintain a minimum amount of contingent capital convertible to equity in times of financial stress."*<sup>8</sup> The Fed is in discussions with bankers. Unlike the existing contingent capital deals that have trigger events related to the issuer's own capital ratio, the Fed is also exploring a system wide trigger.
- (5) Office of the Superintendent of Financial Institutions Canada (OSFI) issued its final advisory on Non-Viability Contingent Capital. Seen as a fast movement on implementation of Basel III, it requires that the regulatory capital of all federally regulated deposit-taking institutions (DTIs) must have loss absorbing quality when the DTI fails. All the non-common Tier 1 and

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<sup>7</sup> COMMISSION SERVICES STAFF WORKING DOCUMENT, "POSSIBLE FURTHER CHANGES," 18-19&23.

<sup>8</sup> Sec 165, "Enhanced supervision," H.R.4173

## *Understanding Contingent Capital*

Tier 2 capital must satisfy the requirement for non-viability contingent capital (NVCC). Unlike CoCo bonds, the trigger event of NVCC is dependent on the regulators' announcement, either from OSFI, or federal/provincial government. Though it sounds like regulators have a lot of discretion, non-viability is determined based on clearly defined criteria which would mitigate the chance of discretion. Interestingly, this is more like a low trigger level, gone concern type of contingent capital compared to the high trigger level, going-concern contingent capital required for GSIB by BCBS.

- (6) Under the Solvency II framework, contingent capital with appropriate feature can be classified as ancillary own fund<sup>9</sup> (AOF). AOF can be used to meet the solvency capital requirement (SCR) but not the minimum capital requirement (MCR). However, according to the directive, the total amounts and the amount for each AOF item are subject to supervisory approval. The recoverability, legal form, and any past exercise need to be taken into account when determining the amount qualified for AOF.<sup>10</sup>
- (7) In August 2010, National Association of Insurance Commissioners (NAIC) Securities Valuation Office (SVO) reported on contingent capital securities. Considering that there is no agreement on the design of the trigger event, the task force did not draw any conclusion but decided to continue monitoring the development of contingent capital.

It is clear that contingent capital is one of the priorities of regulators regarding regulating SIFI but there is still work that needs to be done for further assessment and refinement. Regulators under different jurisdictions may also have different opinions regarding the details.

### **2.4.2 Issuers**

In order to meet more stringent capital requirements, financial institutions can either raise more common equity or issue contingent capital instruments that must convert to common equity upon the occurrence of a trigger event.

Despite the greater complexity and the higher uncertainty of contingent capital, its potential cost is lower than that of common equity. This could increase the capacity for loss absorption and attract more issuers. In addition, the conversion of contingent capital to common equity normally means a dilution of existing shareholders' value. It will discourage shareholders from taking excessive risks above its capacity in the fear of conversion. There is also a chance that contingent capital will be made mandatory by regulators.

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<sup>9</sup> "Ancillary own funds are items of capital other than basic own funds which can be called up to absorb losses." CEIOPS, "QIS5," 308.

<sup>10</sup> "Directive 2009/138/EC," 48.

### **2.4.3 Debt holder**

The investors of contingent capital may be either holders of hybrid securities which will be exchanged for contingent capital as part of the company's restructuring plan or buyers of newly issued contingent capital instruments. In the Lloyds Banking Group's exchange offer in 2009, higher returns and immediate coupon payments motivated the exchange. New buyers may seek for high return and the potential gain from recovery after the conversion of contingent capital.

Like other debt holders, contingent capital investors would discipline the risk taking of stockholders. It is true especially when the conversion price is high, or the chance of recovery is low. However, on the other hand, when the company's financial condition is near the trigger event, in order to get a lower conversion price for conversion at par, investors may short the stocks to drag the stock price further down.

### **2.4.4 Shareholders**

The shareholders' value and role will change if contingent capital becomes an important component of the financial institutions' capital. In the long run, effective contingent capital can improve corporate governance, partly solve agency problem, limit excessive risk taking, and reduce the cost of capital. However, during the conversion of contingent capital, the existing shareholders' value is often diluted. This may encourage more prudent risk taking activities. But the expectation of conversion in the near future will lead to more stock selling, which further lowers the stock price. This downward spiral will exacerbate the financial condition.

### **2.4.5 Rating Agencies**

Rating agencies updated their rating methodologies of hybrid securities in the light of expanding contingent capital markets. It is a critical factor to consider when setting the price of contingent capital instruments. The view of rating agencies is also important for financial strength ratings when contingent capital becomes sizable in loss absorbency.

### **Debt Instrument**

Contingent capital instruments that are rated as debt instruments normally receive ratings lower than investment grade.

In 2009, S&P issued a rating criterion for contingent capital. Contingent capital is defined as "*debt and hybrid securities that contain triggers that convert them into equity or some other Tier-1 instrument.*"<sup>11</sup> S&P believes that the proposed contingent capital increases the risk of loss to the investors, compared to plain vanilla bonds. Contingent capital securities would receive lower credit ratings than similar ones

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<sup>11</sup> "Standard & Poor's Ratings Services Criteria Regarding Contingent Capital," 2.

## Understanding Contingent Capital

without the conversion option. Conversion of capital securities will be treated as default.

Moody's classifies contingent capital into 3 groups: rate, no rate, and may rate. Moody's only rates "securities that feature triggers for conversion that are credit-linked, objective and measurable and where the impact of conversion can be estimated." For triggers that are at the issuer's discretion or unrelated to the financial condition of the issuers, there will be no rating. When assigning the rating, the major considerations are "the risk that the 'host' security might absorb losses for a 'going' concern, and the expected loss severity upon conversion based on the conversion ratio and the likely value that would be received by investors at that point in time. Important considerations would include the type and transparency of the trigger, how it is calculated, and over what time horizon." Moody's is also concerned with contingent capital instruments that have trigger events based on a regulatory capital ratio. "Because many banks currently operate in rapidly changing regulatory and political environments, a lack of clarity on legal triggers and an overall resolution framework would prevent Moody's from assigning a rating at this time."<sup>12</sup>

### Equity Instrument

When doing financial analysis, S&P considers a high trigger level and timely conversion critical for qualifying for an equity instrument, as stated below.

"The conversion would need to happen early enough in the issuer's credit deterioration to be able to make a difference to that decline. A trigger level set at the regulatory capital threshold--or very close to it--is generally insufficient in our view to warrant equity-like treatment in advance of actual conversion. Similarly, if the conversion mechanisms allow for a potential significant lag after the trigger breach, we would not view the security as equity-like. Such lags could arise from stipulated delays or from pragmatic considerations, such as infrequent trigger measurement dates."<sup>10</sup>

Moody's determines the amount of equity credit for contingent capital based on their structures. Moody's thinks that "triggers have generally not proven to be fail-safe in terms of their ability to accurately identify credit deterioration."<sup>11</sup> It is also difficult to ignore its similarity to debt instruments such as the fixed coupon rate and the need of refinance after the maturity of contingent capital.

Rating agencies focus on whether the trigger event is clear and objective, and whether it will result in timely conversion, which is the key to determine its effectiveness of loss absorption.

## 2.5 Some Doubts about Contingent Capital

Most of the contingent capital securities issued to date have trigger events linked to the capital ratio of the issuer. Given that the major goal of regulators and issuers is to reduce systemic risk exposure, there are doubts about the effectiveness of risk mitigation and the future of contingent

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<sup>12</sup> Moody's, "Rating Considerations," 1-6.

## *Understanding Contingent Capital*

capital. Investors and researchers have voiced many suspicions about the contingent capital instruments.

- (1) Most of the trigger events used so far are based on the company's own core tier 1 capital ratio, a regulatory capital adequacy measure. This might not provide timely conversion considering the fast downward slide during a crisis.<sup>13</sup> There are also concerns about using the capital ratio, a measure based on market value. In a stressed situation, the owners of contingent capital, anticipating a drastic drop in equity price and occurrence of the trigger event in the near future, may short the stocks and exert pressure on the stock price. By doing this, they can get a lower conversion price. Stockholders may sell the stocks with the expectation of such behavior. This downward spiral may totally devour the benefits of the conversion and dilute the value of existing stockholders.
- (2) To mitigate systemic risks and reduce the need of government bailouts for systematically important financial institutions, the market size of contingent capital needs to be big enough.<sup>14</sup> New features of contingent capital cause difficulty and uncertainty for both the pricing and valuation of this new type of hybrid security. Its higher risk and the lack of knowledge and experience may daunt many investors. There are also investors who have an investment policy that disallows equity market investment or have a limit on equity allocation. They may not be able to invest in contingent capital. In addition, when contingent capital is converted to common equity, they may be forced to sell the stocks, which may have a big market impact and more loss. This is also a potential impediment for the development of the contingent capital market.
- (3) There have been hot discussions about contingent capital's impact on systemic risk. Some argue that the trigger event should be based on the loss of an industry, or the whole financial system, instead of the issuers' own loss.<sup>15</sup> In this way, contingent capital is only used for managing systemic risk. The issuer is able to raise capital using traditional methods such as rights issues if the issuer gets into trouble due to its idiosyncratic risk. Others argue that an industry-wide trigger may increase the systemic risk instead of decreasing it. If the trigger is at the discretion of the regulators, they might be reluctant to trigger the conversion. If contingent capital is triggered or is near the trigger point, it will convey a very clear adverse message to the market which may lead to overreaction of investors and therefore more

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<sup>13</sup> Hillion and Vermaelen, "Death Spiral Convertibles," 3-6; MacDonald, "Contingent Capital," 11.

<sup>14</sup> Maes and Schoutens, "Contingent Capital," 7.

<sup>15</sup> Squam Lake Working Party, "An Expedited Resolution," 4.

## *Understanding Contingent Capital*

downward pressure.<sup>16</sup>

- (4) While contingent capital may boost the issuer's capital adequacy ratio, it may not be able to solve the liquidity issue, which is normally the direct reason for bankruptcy in a financial crisis. Converting contingent capital instruments such as CoCo bonds to equity will reduce future liquidity requirements such as interest payment. However, unlike other capital raising activities such as rights issue or government bailout, it will not inject liquid assets.
- (5) Regulators showed great interest in exploring contingent capital instruments to help prevent the next financial crisis and reduce the usage of taxpayers' money to support system important firms. However, the rule is still vague and under development. If regulators in different regions have different rules for contingent capital, especially on qualification requirements, it could be a difficult situation for global banks and insurers.
- (6) Contingent capital might reduce the disciplining power of the debt holders. As Koziol and Lawrenz (2011) showed in a model, when the managers have the discretion of risk taking activities, the bank's probability of financial crisis will be increased by having contingent capital.<sup>17</sup> In addition, there may be an increase in agency cost of equity and therefore the cost of debt due to the reduction in managerial ownership.

### **3. KEY FEATURES**

There are many proposals for using contingent capital to solve the recapitalization issue faced by the shareholders and the too-big-to-fail issue faced by the regulators in a financial crisis. Although contingent capital is seen as a promising candidate to increase the capitalization level and reduce the possibility of government bailout, it does not have a mature market yet. Different opinions of the appropriate design and its complicated features justify more analysis and tests on the market before a full endorsement. This section will discuss the key features of contingent capital that are critical for fulfilling its goal in a practical way. The prominent designs and opinions of contingent capital will also be described.

#### **3.1 Trigger Event: Rule-Based or Discretionary**

The designs of contingent capital instruments include the trigger event based on clearly specified rules or at the regulators' or issuers' discretion. For industry-level trigger events, there are different

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<sup>16</sup> Goldman Sachs, "Contingent Capital," 7, has a discussion about the problems with using a trigger based on regulatory discretion.

<sup>17</sup> Koziol and Lawrenz, "Contingent Convertibles," 18-34.

## *Understanding Contingent Capital*

opinions about the appropriate choices. For institution-level trigger events, there seems to be a mutual preference of using a rule-based event. Contingent capital instruments with a rule-based trigger event are perceived to be more transparent, predictable, and attractive to potential investors. It is also easier to price.

Acharya et al. (2009) think that an industry-level trigger must be rule-based, rather than at the discretion of regulators. With a discretionary feature, the occurrence of trigger would convey severe adverse news to the market, causing a possible downward spiral. In contrast, a rule-based trigger would be well-anticipated and would not have such consequences. In addition, the political pressure on the regulators for the announcement of conversion is not trivial due to its signaling effect. Squam Lake Working Group (2009) has a different opinion for the rule-based industry-level trigger: they are concerned that the aggregate data regulators might use are likely to be imprecise, subject to revisions, and measured with time lags.

Rating agencies require an objective and rule-based trigger event as one of the preconditions for assigning a credit rating. Therefore, a rule-based trigger event is more promising from the perspective of the marketability of contingent capital instruments.

The capital access bond (CAB) proposed by Bolton and Samama (2011) is an exception for institution-level trigger event. The issuer has the option to convert the CAB into equity at the pre-specified price and also has the full discretion on the conversion. Technically speaking, the conversion is still based on rules. The conversion will happen if the option is in the money at maturity. However, as pointed out by the designers, the signaling effects might prevent a decision based solely on the payoff of the option. Not converting the CAB when the conversion price is less than current market price of the stock could be conceived by the market as a higher equity value, which has a positive impact. Or the bank's rational management will be questioned, which has a negative impact.

### **3.2 Trigger Event: Institution Level and/or Industry Level**

Existing proposals of contingent capital have a conversion trigger based on the issuer's financial condition and/or on an industry-wide indicator. The issuer's financial conditions can be indicated by its stock price, capital adequacy ratio, or book value of equity. Industry-wide indicators include aggregated market loss indices and financial industry loss indices. There is no mutual agreement on the type of trigger events to be used among the academic and the industry. Up till now, most existing contingent capital deals are based on an institution-level trigger.

An institution-level trigger event has a focus on the financial condition of the issuer. It is not



## *Understanding Contingent Capital*

directly linked to systemic crisis. Therefore, contingent capital with institution-level trigger absorbs loss caused by systemic risk and non-systemic risk. Someone might have concerns about the unnecessary protection for firms taking more than necessary non-systemic risk. Flannery (2009) pointed out that systemically important firms cannot be permitted to fail, as it might cause market turbulence, no matter what the cause is. The prevention from bankruptcy due to non-systemic risk might help protect the incapable managers. Flannery (2009) argued that it is a general corporate governance issue and is not something new brought by contingent capital. Contingent capital can at least protect the taxpayers as intended.

An industry-level trigger event may be more suitable for mitigating systemic risk. With the industry-level trigger in place, contingent capital instruments will be converted only in a systemic crisis. However, it may be hard to implement in an objective way and may convey an adverse message to the market upon conversion. If the industry-level trigger is at the regulators' discretion, due to the signaling effect of conversion, there is political pressure which might delay the triggering and therefore cause more loss. A trigger event that is solely based on the industry-level condition could act as an disincentive for sound risk management, as all the firms are treated the same, no matter how much systemic risk they contribute to the industry.

Some proposals include a dual trigger based on both an institution level condition and an industry level condition. Only when both conditions are true will the conversion be automatically triggered. Examples include Squam Lake Working Group (2009) and McDonald (2011).

### **3.3 Trigger Event: Based on Book Value or Market Value**

Another key element of trigger events is the basis of value measurement. It could be a book value measure which is based on accounting rules or regulatory rules. Or it could be a market value measure determined by investors. Both types of measurement have their own shortcomings but a measure based on market value is preferred by the academic community.

Using a trigger event based on market value might cause the following issues.

- (1) Book value of equity is subject to the adjustment of management. Given the current level of complexity of financial institutes, a management team has leeway to move accounting entries off the balance sheet, and therefore the equity under GAAP or IFRS could be manipulated.
- (2) Book value of equity is a backward-looking measure for some accounting frameworks such as U.S. GAAP, where historical cost plays an important role in valuation.
- (3) The reporting of financial conditions is not continuous. The timing of the trigger that is

## *Understanding Contingent Capital*

based on the financial reports might lag behind the time when recapitalization is needed based on market condition. The timing issue might prevent the contingent capital from being converted to equity before the company goes bankrupt or receives government aid.

A trigger event based on market value will not have these issues. However, it has its own problems.

- (1) The stock price is subject to market manipulation. The impact could be quite significant for contingent capital whose conversion will cause material dilution of shareholders' value.
- (2) As pointed out by Flannery (2009), stock price is subject to random pricing errors and therefore random elements in the conversion based on the stock price. The impact is more prominent for the design where conversion price is the same as the then-current market price at the date of the conversion. However, the impact could be dampened if the conversion price is set to be the average of the daily market prices in a certain time period with a fixed length.

Acharya et al. (2009) and Flannery (2009) clearly state in their reports that a market-based trigger is more appropriate due to its timeliness and less exposure to managerial manipulation. However, some existing arrangements have a capital adequacy ratio based trigger event which is a book value measure based on regulatory rules. Lloyds Banking Group's ECNs and Rabobank's senior contingent notes issued in 2009 are real examples. The reasons for choosing a capital adequacy ratio might be the following.

- (1) Using a capital adequacy ratio is straightforward regarding the goal of reducing the possibility of default or government bailout, although the failure to fulfill obligation might be caused directly by liquidity issue.
- (2) Some arrangements have the level of the trigger well above the minimum requirement, so timeliness would be less of an issue. The conversion is more likely to happen before the issuer becomes insolvent.

### **3.4 Conversion Price**

Conversion price determines how many shares investors will get if the conversion is triggered. It could be set as:

- (1) A fixed value, such as the stock price at the issue date of the contingent capital instrument. Some contracts specify the number of shares to be received upon conversion instead of the conversion price.

## *Understanding Contingent Capital*

- (2) The stock price at conversion, which is also known as par conversion.
- (3) The stock price at conversion with a floor.
- (4) The stock price at conversion with a discount or a premium.

As a variant, the stock price at conversion could be determined as the average of daily stock prices at and before the conversion.

McDonald (2011) provided a comprehensive analysis of different types of conversion price, including fixed share conversion, fixed dollar conversion, par conversion, premium conversion, and discount conversion.<sup>18</sup> Most discussions on how to choose a conversion price are about the implication on the dilution of shareholders' value ([Section 4.2](#)), potential price manipulation ([Section 3.5](#)), and multiple equilibria of the market equity trigger ([Section 3.6](#)).

### **3.5 Market Manipulation**

Market manipulation is one of the major concerns for the effectiveness of contingent capital in reducing systemic risk. The investors of the contingent convertible bonds might short sell the issuers' stock to limit their loss. Short selling is more likely when the stock price drops to a level close to triggering. If it is a conversion at par, there is more incentive to bring down the stock price, as it means more value transferred from shareholders to investors of contingent capital. Anticipating this, existing stakeholders will also sell their holdings to reduce their loss as soon as possible when the stock price is close to the conversion point. This will put extra pressure on the stock price. This phenomenon is known as the death spiral. The death spiral impact of convertible securities is not something entirely new. Hillion and Vermaelen (2001) investigated the death spiral convertibles<sup>19</sup> and found that material loss occurred for the investors.

However, whether the death spiral will continue after the conversion is questionable. If the stock price is too low, there might be less liquidity and a higher bid-ask spread. If the loss is material, investors might want to buy shares instead of selling them with the hope of a recovery or government bailout.

Some adjustment of the conversion price might offset the impact of market manipulation. McDonald (2011) argued that a fixed share premium convertible structure is least exposed to

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<sup>18</sup> McDonald, "Contingent Capital," 5.

<sup>19</sup> "Death spiral convertibles are privately held convertible securities (preferred stock or debentures) with a conversion price that is set at a discount from the average (or sometimes the minimum) of past stock prices in a look-back period." Hillion and Vermaelen, "Death Spiral Convertibles," 1.

## *Understanding Contingent Capital*

manipulation. The lower the stock price is, the less the value after conversion. A conversion with premium means a further reduction of value after conversion. In fact, investors might influence the stock price in the opposite direction to avoid conversion. However, it is more difficult to push up the stock price if the issuer is in distress.

Another commonly suggested way of preventing market manipulation is to determine the conversion price as the average of the past  $n$  days' stock price prior to the conversion. McDonald (2011) and Flannery (2009) suggested that this feature makes it more difficult for manipulation due to the lengthened period of holding short positions. The disadvantage of this structure is that the conversion might be delayed. Squam Lake Working Group (2009) also pointed out another possible manipulation: "*If the stock price falls precipitously during a systemic crisis, management might intentionally violate the trigger and force conversion at a stale price that now looks good to the stockholders.*"<sup>20</sup>

Flannery (2009) and McDonald (2011) also examined the possibility of retiring the contingent capital upon conversion gradually and randomly to avoid a huge gain from price manipulation. As pointed out by Flannery (2009), forbidding holders of contingent capital to short sell the issuer's stock is also a possible solution.

Another potential method of price manipulation is share repurchase. If the conversion is believed to be highly probable to occur, with a material value dilution, the issuer has an incentive to prevent the conversion by putting upward pressure by share repurchase. McDonald (2011) thinks that the impact would be small. If the market thinks that the goal of share repurchase is to avoid conversion, it will have a negative impact on the share price, and so it might not actually happen.

### **3.6 Multiple Equilibria**

One interesting conclusion by Sundaresan and Wang (2011) is that multiple equilibria or no equilibrium may exist for contingent capital with a market trigger.<sup>21</sup> When the stock price is close to the trigger point, there could be different speculation on the occurrence of conversion. The equilibrium stock price near conversion could be different depending on whether or not the conversion will happen. Two equilibrium prices are possible: (1) the equilibrium price which is above the conversion price, assuming there will be no conversion; and (2) the equilibrium price which is below the conversion price, assuming there will not be conversion.<sup>22</sup> Sundaresan and Wang (2011) point out that multiple equilibria are caused by the value transfer between shareholders and

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<sup>20</sup> Squam Lake Working Group, "An Expedited Resolution," 5.

<sup>21</sup> Market trigger is a trigger on market value of equity.

<sup>22</sup> Mathematical deduction and numerical examples can be found in Sundaresan and Wang, "On the Design," 9-12.

## *Understanding Contingent Capital*

contingent capital holders. The value transfer upon conversion will cause a sudden change in the stock price, the source of the difference in multiple equilibrium prices. However, this would not be an issue if the conversion is made at par,<sup>23</sup>

If the conversion is not timely, the stock price can fall below the trigger point before the conversion of a CoCo bond. Sundaresan and Wang (2011) argue that there is no equilibrium price in this situation. If the conversion is believed to happen, the stock price will fall below the conversion price and the conversion will happen. If the conversion is believed not to happen, the stock price will be higher than the conversion price. Both scenarios are not consistent with the assumption that the stock price could fall below conversion price without a conversion.

Prescott (2011) illustrated that a trigger on the market of equity could potentially cause multiple equilibria and nonexistence of the equilibrium. Based on the market experiment data and empirical evidence, it is argued that a market equity trigger “*made prices and allocations less efficient and led to numerous conversion errors.*”<sup>24</sup>

Theoretically, the lack of a unique price indicates an unstable market and a high exposure to price manipulation. The market price would therefore not represent its true economic value and might cause market inefficiency. However, the nonexistence of equilibrium happens when the stock price is near the trigger point. Given that contingent capital is used to deal with financial distress, the stock price is volatile during that period even without the presence of contingent capital. At that time, the equity market is in an unstable situation and the stock price is highly driven by the psychological factors of investors and sensitive to any new information. Multiple equilibria or the absence of equilibrium caused by contingent capital may make it more complicated, but not necessary worse. The market expectation of the occurrence of conversion will be determined by market participants, just as participants determine the stock price. When the expectation changes, the stock price can suddenly jump. A jump in stock price is not abnormal when the company is in financial distress. Other investor behaviors may also dominate the movement of stock price and push it to a certain equilibrium price. For example, the short selling behavior as discussed in Section 3.5 may move the stock price quickly until at or below the conversion price.<sup>25</sup> It would eliminate one of the two possible equilibrium prices. Therefore, multiple equilibria may not cause chaos in practice.

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<sup>23</sup> A conversion at par indicates that there is no value transfer between shareholders and contingent capital investors.

<sup>24</sup> Prescott, “Contingent Capital: The Trigger Problem,” 15.

<sup>25</sup> There is incentive for short selling behavior as long as the conversion price is linked to the then-current equity price even if the conversion is not at par.

## *Understanding Contingent Capital*

Contingent capital instruments with trigger events based on book value, regulatory solvency ratio, and industry level loss are less exposed to the issue of multiple equilibrium. Although some trigger events are highly correlated with stock price and there could be value transfer between contingent capital holders and shareholders, the complexity and the uncertainty of the accounting and regulatory rules make it difficult to speculate based on the occurrence of conversion and the equilibrium price. Importantly, note that placing the trigger on firm value is not equivalent to placing the trigger on the market equity ratio. A trigger based on firm value is not affected by the multiple equilibrium issue.

### **3.7 Proposals**

There have been many proposals about the appropriate design of contingent capital since 2008 from the academic community. Some of them are described below to illustrate the variety, complexity, and the ongoing development of contingent capital market.

Squam Lake Working Group (2009) suggested a conversion from debt to equity if two conditions are met. The first condition is an industry-level event such as a declaration by regulators that the financial system is suffering from a systemic crisis. The second is an institution-based event such as a violation of covenants in the hybrid-security contract. A promising candidate of the covenant is the capital adequacy ratio (Bank's Tier 1 Capital/risk adjusted assets).

McDonald (2011) analyzed a dual trigger design based on the firm's stock price and the value of a financial institutions index. This structure potentially protects financial firms during a crisis, when all are performing badly, but during normal times it allows a bank with bad performance to go bankrupt.

Kashyap et al. (2008) proposed using capital insurance that would "*transfer more capital onto the balance sheets of banking firms in those states when aggregate bank capital is, from a social point of view, particularly scarce.*"<sup>26</sup> It is an insurance contract, not like a contingent convertible bond. The trigger of insurance payoff is based on the capital loss of the total banking industry. The insurance payment can help strengthen the solvency position and provide liquidity.

Flannery (2009) proposed "*Contingent capital certificates*" (CCC) that "*would be issued as debt obligations, but would convert into common stock if the issuer's capital ratio fell below some critical, pre-specified value.*" It is suggested to be applied to systemically important firms. However, the condition of conversion and its specification are complicated compared to other proposals. Flannery's key features are quoted

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<sup>26</sup> Kashyap et al., "Rethinking Capital Regulation," 452.

## Understanding Contingent Capital

below.

- a. *A large financial firm must maintain enough common equity that its default is very unlikely.*
- b. *This common equity can satisfy either of two requirements:*
  - *Common equity with a market value exceeding 6% of some asset or risk aggregate.*
  - *Common equity with a market value exceeding 4% of total assets, provided it also has outstanding subordinated (CCC) debt that converts into shares if the firm's equity market value falls below 4% of total assets. The subordinated debt must be at least 4% of total assets.*
- c. *The CCC will convert on the day after the issuer's common shares' market value falls below 4% of total assets.*
- d. *Enough CCC will convert to return the issuers' common equity market value to 5% of its on-book total assets.*
- e. *The face value of converted debt will purchase a number of common shares implied by the market price of common equity on the day of the conversion.*
- f. *Converted CCC must be replaced in the capital structure promptly.*
- g. *The CCC debt converts automatically – no option. If the firm is insolvent when conversion is triggered (e.g., because of a jump in asset values), the debt covenants must specify a conversion price that wipes out the previous shareholders.*
- h. *CCC cannot be owned by systemically important firms for their own account.*
- i. *The CCC that will be converted need to follow some selection rules such as retiring the shortest maturity, random selection, and according to the seniorities of the CCC.<sup>27</sup>*

Bolton and Samama (2011) proposed the capital access bond (CAB), "*which gives the issuer of the bond the unconstrained right to exercise the option to repay the bond in stock at any given time during the life of the bond. It is effectively an option to issue equity at a prespecified price, with the added feature that the writer of the option puts up collateral to guarantee that it is able to fund the purchase of new equity should the buyer of the put option choose to exercise the option.*"<sup>28</sup> This is quite similar to the reverse convertible bond that may be converted into stock or its cash equivalent at maturity or at some triggering event. CAB has two embedded options: a call option on the bond and a put option on the shares. Unlike the traditional convertible bond, both options are owned by the issuer. The idea of issuing multiple CABs with

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<sup>27</sup> Flannery, "Stabilizing Large," 9-11.

<sup>28</sup> Bolton and Samama, "Capital Access Bonds," 10.

different strike price is also discussed to deal with all kinds of contingencies in a crisis.

Calomiris and Herring (2011) proposed a contingent capital instrument with a quasi market value based equity-ratio trigger designed to smooth the impact of the fluctuations in share prices. It is calculated as the 90-day moving average of the ratio of the market value of equity to the sum of the market value of equity and the face value of debt. The bond is not expected to be converted but will promote more efficient corporate governance. The trigger event is designed to be less exposed to manipulation. The conversion price is also set to have a material dilution of shareholders' value.

The diversity of the proposals listed indicates that contingent capital is still under development both in theory and in practice. The surveys of the existing literature on contingent capital are not rare. Calomiris and Herring (2011)<sup>29</sup> did a comparison of different designs regarding the amount of CoCo bonds required to be issued, the trigger event, and the term of conversion. Cooley et al. (2010)<sup>30</sup> summarized the types, the trigger events, whether they are equity based or credit based, whether they have market value trigger or book value trigger, and the drawbacks.

### **3.8 Post Conversion**

#### **Ownership**

There are concerns that the conversion of contingent capital gets the distressed firms out of trouble and at the same time keeps the incompetent management team. As Flannery (2009) pointed out, it is a general corporate governance issue and is not something new brought by contingent capital. Collender et al. (2010) mentioned that contingent capital could "*require the replacement of or votes to replace management and the board of directors*"<sup>31</sup> if a certain amount of contingent capital has been converted. There are concerns that contingent capital might dampen the disciplining power of debt holders. Allowing the replacement of management and board of directors might be a good idea, as this threat may discourage the management to take aggressive actions trying to recover their loss without caring for the downside risk. Such kind of terms written in the contingent capital contract would make it a complete contract<sup>32</sup> where the probability of default is shown by Koziol and Lawrenz (2011) is reduced.

#### **New Issuance**

After contingent capital is converted, it is hoped that the firm will return to a healthy condition.

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<sup>29</sup> Calomiris and Herring, "Why and How," 42-46.

<sup>30</sup> Cooley et al., "Regulating Wall Street," 168-174.

<sup>31</sup> Collender et al, "Automatic Recapitalization," 13.

<sup>32</sup> Koziol and Lawrenz, "Contingent Convertibles," 14-18.



However, the firm will have no or less automatic bail-in securities after conversion. Therefore, it is necessary to issue new contingent capital instruments in a short period to regain the protection.

### **3.9 Contingent Capital versus Other Risk Transfer Instruments**

The insurance industry has a history of transferring risks through traditional reinsurance arrangements and alternative risk transfer instruments. The majority of the risks involved are insurance risks such as catastrophe risk, mortality risk, longevity risk, and lapse risk. Others usually help transfer all the risks of the written business, including financial risks to a third party. This section compares those existing risk transfer instruments to the relatively new contingent capital instruments. They are all utilized for risk mitigation but their focuses are quite different.

#### **Traditional Reinsurance Arrangement**

Reinsurance has been used by insurance companies to transfer undesired risks, stabilize their claim experience, increase their capacity of writing new business, and improve the efficiency of capital usage. Depending on the type of reinsurance arrangement, specific risks or all risks of insurance business are transferred from the primary insurer to the reinsurer. It is quite different from contingent capital in the following aspects.

- (1) The loss-absorbing capacity of the reinsures is less than the potential market for contingent capital, the whole capital market.
- (2) Reinsurance deals with the risk on the liability side, while contingent capital works as a buffer for the risks from both the asset side and the liability side.
- (3) The primary insurer is exposed to counterparty risk, since the reinsurer may fail to pay the reinsurance claim. That is not the case for the issuer of contingent capital, since the price is paid at the issue date.
- (4) Contingent capital provides funds under distressed situations when the conversion option is exercised, while reinsurance is used as a general risk transfer channel. From the perspective of maximizing the risk adjusted return on capital, contingent capital is probably a better choice given the relatively high cost of buying reinsurance protection.

#### **Insurance Derivatives**

There are several types of non-traditional financial instruments that have payments contingent on a certain insurance event, loss, or experience. Those insurance derivatives are used to transfer insurance risk to reinsurers or general investors.

### *Understanding Contingent Capital*

- (1) Industry loss warranties (ILWs) deal with the loss caused by insurance events such as hurricanes, windstorms, and earthquakes. The owner of the contract will get paid a specified amount if the industry loss caused by the disaster exceeds the trigger level.
- (2) Catastrophe bonds are sold to reduce the exposure to catastrophe risk. The investor will get a rich coupon payment but will lose the coupons and/or the principle once a catastrophe event occurs.
- (3) Longevity bonds have the amount of coupon payment linked to the number of survivors for a chosen population cohort. It is often used to hedge the risk that one outlives his/her savings. Insurance companies buy longevity bonds to protect them against the risk that the mortality experience is better than what is assumed when pricing life annuities.

In contrast, contingent capital focuses on the financial risks, especially the systemic risk. In addition, the conversion is expected to happen only under financial stress. The writing down of liability or the conversion to equity helps strengthen the capital position. The insurance derivatives are used to limit the loss no matter whether the buyer is in financial trouble or not.

#### **Sidecar**

A sidecar, an arrangement that allows the investors to get the return and take the risk of insurance business, can be used to enhance the insurers' ability to take risk. Normally, a special-purpose vehicle (SPV) needs to be established. The insurer pays a premium to the SPV and the investors deposit money to the SPV to cover the claims by policyholders. It is similar to quota-share reinsurance that transfers part of the business and risk to the reinsurer. The insurer transfers the written business to the investors through the sidecar. However, the entire risk is not transferred. The loss of the investors is limited to the funds that are put in as required. When the realized experience is worse than what the fund can cover, the insurer has to bear the remaining loss. However, the required fund value is normally high enough so that the chance of excess loss is slim.

A sidecar helps reduce the risk exposure and the reserve that is required to support the transferred insurance business. Both sidecars and contingent capital have a positive impact on the capital position, but they are meant to meet different challenges.

- (1) The return and risk is transferred to outside investors for certain written business through the sidecar. However, contingent capital is normally linked with the risk of the whole portfolio, including the retained business as well.
- (2) The sidecar is normally arranged to optimize the usage and efficiency of the capital and increase the risk-taking capability. When an insurer or reinsurer finds a profitable investment

## *Understanding Contingent Capital*

opportunity but does not have enough capital to invest, it may consider using a sidecar to release some used capital to take the opportunity. In contrast, contingent capital is deployed to increase the loss absorbing capability and reduce the risk of insolvency. Therefore, a sidecar is used to prepare for taking more risks while contingent capital is used to prepare for future distressed situations.

### **Catastrophe Equity Put**

Catastrophe equity put (CEP) is a special type of contingent capital with a focus on the catastrophe risk. Given the material impact of catastrophe events on the loss and stock price of insurance companies, CEP appears to be an effective tool to mitigate the risk by flooring the equity value. Compared to standard equity put option contracts, it requires two conditions to be met contemporarily before exercising the option.

- (1) The equity price drops below the exercise price
- (2) The catastrophe loss exceeds the prespecified amount

Whereas other contingent capital instruments normally have triggers related to the general financial health condition of the issuer or the financial industry, CEP is used for mitigating catastrophe risk only, not financial systemic risk or any other kinds of risk. CEP and other types of contingent capital are not exclusive but complementary.

### **Line of Credit**

A line of credit may be more appropriately termed a risk mitigation tool rather than a risk transfer instrument. It is a source of financing provided to credit-worthy companies or individuals by banks. The borrower can use the fund and need to pay interests and other related fees. Insurance companies, especially when publicly listed, often use line of credit to increase its available liquidity source and therefore help reduce the exposure to liquidity risk.

Lines of credit and contingent capital are designed for different purposes. Lines of credit only allow the company to borrow extra cash at a cost. They do not change the composition and amount of the surplus account. When there is a capital inadequacy problem, borrowing money will not be helpful, as cash borrowed will be reflected on the liability side as well. Available capital will hardly change. On the other hand, the conversion of contingent capital will lead to a direct liability written down or an increase in the available capital. These two sources of financing deal with different kinds of risk and therefore they behave differently in many aspects.

## **4. EFFECTIVENESS AND POTENTIAL IMPACT**

### **4.1 The Impact on Systemic Risk**

Systemic risk is the risk that the entire financial system may collapse. Due to the interdependence within the financial system, the failure of one or more systemically important firms can lead to the crash of the entire system. Contingent capital is believed to reduce the systemic risk and default probability when compared to pure debt instruments. Issuing contingent capital without reducing the common equity provides additional capital which would certainly reduce the chance of bankruptcy. However, substituting common equity with contingent capital to meet capital requirement might have an uncertain impact on systemic risk due to the uncertainty of the conversion.

The effect of reducing systemic risk was shown by Hilscher and Raviv (2011) analytically via a quantitative model. Based on the model setup, contingent capital financing can reduce the default probability compared to subordinate bond financing. In addition, the risk-taking incentive becomes less if the conversion price indicates a certain level of value dilution for the existing shareholders.

Although a properly designed contingent capital may reduce systemic risk, it is not expected to be the entire solution for the too-big-to-fail issue. McDonald (2011) emphasized that the proposed dual trigger contingent capital instrument reduces a firm's debt load but is not used to address the too-big-to-fail issue. Regulators need to "*proactively monitor the management and performance of financial institutions. Contingent capital is thus a backstop for regulatory failures or unforeseen market events, not a regulatory substitute.*"<sup>33</sup>

Acharya et al. (2009) also pointed out that contingent capital is not enough for eliminating systemic risk. Even when the issuers in trouble remain solvent due to the timely conversion from debt to equity, the firms are still exposed to liquidity risk which is normally the direct cause of going bankrupt. Counterparty risk also exists, although it is expected to be lower if every firm's contribution to systemic risk is reduced by issuing contingent capital. The loss in excess of the value of the equity and contingent capital for too-big-to-fail firms is still likely to be protected by the government. Therefore, there is still an incentive to take risk above a firm's capability. Acharya et al. (2009) concluded that "*an explicit fee ... charged to banks in good times based on their expected losses and their systemic risk contributions*" is necessary for rectifying the moral hazard due to the implicit guarantee by the government.

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<sup>33</sup> McDonald, "Contingent Capital," 2.

## **4.2 Dilution of Shareholder Value**

When the conversion price is set to be equal to the market price, there is material dilution of shareholder's value on the conversion of the CoCo bond. A fixed or floored conversion price will limit the dilution. With the threat of value dilution upon conversion, existing shareholders are discouraged from taking excessive risk above their risk tolerance. However, by fixing the conversion price to be the stock price at the issue date of the CoCo bonds, the magnitude of dilution of the shareholder's value is floored. It might not provide enough incentive for disciplined strategic planning. Calomiris and Herring (2011) mentioned that in the interests of creditors and regulators who are more risk averse, a dilution of shareholders' value is critical for a more stringent control on risk-taking activities.

Investors' behavior could also have an impact on the value transfer from equity holders to the contingent capital investors. If the contingent capital instrument has a conversion price equal to the then-current stock price, contingent bond holders will probably short sell the stock near the trigger point as a sharp drop in stock price is favorable. Low stock price means a high value transfer. Shareholders who foresee this behavior will also sell their shares as soon as possible, hoping to get a higher price than the conversion price.

## **4.3 Capital Admittance and Accounting Treatment**

The regulation and financial reporting rules have been evolving and it is not crystal clear at this point what the final decision will be for the treatment of contingent capital instruments.

### **Capital Admittance**

Under the current capital requirements directive (CRD II) of European Union, instruments that absorb losses on a going-concern basis and that must be converted to core Tier 1 capital are regarded as equity capital, capped by 50% of the core Tier 1 capital. Contingent capital instruments with those features are likely to be classified as Tier 2 capital under current framework. According to the consultation paper (CRD IV) issued in 2010, European Commission will consider the potential need for all non-core Tier 1 instruments to have a mandatory principal write-down or conversion feature, the potential triggers for conversion, and alternative mechanisms and triggers of contingent capital.<sup>34</sup> Therefore, it is possible that certain types of contingent capital instruments could qualify for non-core Tier 1 capital.

As written in a future rule about the additional loss absorbency requirements for global

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<sup>34</sup>COMMISSION SERVICES STAFF WORKING DOCUMENT, "POSSIBLE FURTHER CHANGES," 18-19&23.

## *Understanding Contingent Capital*

systematically important banks (GSIB) released by Basel Committee on Banking Supervision (BCBS) in late 2011, contingent capital will have to be converted to Common Equity Tier 1 when the Common Equity Tier 1 falls below 7% of risk adjusted assets. It also sets a cap on the new shares and requires a full authorization from the issuers for an immediate conversion.

Under the Solvency II framework, contingent capital with appropriate feature can be used to meet the solvency capital requirement (SCR), but not the minimum capital requirement (MCR). However, the amounts of ancillary own fund (AOF) items and the amount for each AOF item are subject to supervisory approval.<sup>35</sup>

In its final advisory on Non-Viability Contingent Capital, the Office of the Superintendent of Financial Institutions Canada (OSFI) requires that the regulatory capital of all federally regulated deposit-taking institutions (DTIs) must have a loss-absorbing quality when the DTI fails. All the non-common Tier 1 and Tier 2 capital must satisfy the requirements for non-viability contingent capital (NVCC). However, the trigger event of NVCC is at the discretion of the regulators. Contingent capital instruments that meet the requirements are likely to qualify for either non-common Tier 1 or non-common Tier 2 capital.

In the United States, the treatment of contingent capital is not clear, both for the banking industry and the insurance industry.

### **Accounting Treatment**

There is, as of yet, no guidance issued for contingent capital regarding the accounting treatment. According to IAS 32, under IFRS, convertible bonds need to be presented as two components on the issuer's balance sheet:

- (1) A financial liability whose value is determined by measuring the fair value of a similar liability that does not have the conversion option, and
- (2) An equity instrument whose value is determined as the fair value of the option to convert the instrument into ordinary shares.

Unlike convertible bonds, the conversion option of contingent capital instruments is rule-based or at the discretion of the issuer or the regulators, not the investors. It is likely that contingent capital instrument will be presented as two components under IFRS in the same way, except that the value of the equity instrument depends on a different option.

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<sup>35</sup> "Directive 2009/138/EC," 48.

## *Understanding Contingent Capital*

In IAS 32, it is mentioned that “*Classification of the liability and equity components of a convertible instrument is not revised as a result of a change in the likelihood that a conversion option will be exercised, even when exercise of the option may appear to have become economically advantageous to some holders.*”<sup>36</sup> The arguments are that the holders may not always act in the way that might be expected and the likelihood of conversion will change from time to time. Certainly, the same arguments also apply to contingent capital. It is likely that under IFRS, once the classification of the liability and equity components is determined at issuance, it will be kept the same until it is converted.

U.S. GAAP has different treatment for convertible bonds from IFRS. According to FAS 133, for the issuer convertible bonds without the cash settlement option should not be separated into two components, as its stock price is closely related to the convertible bonds. On the other hand, for the investors, the embedded conversion option needs to be separated from the debt component under U.S. GAAP. Contingent capital might get different treatment given that regulators consider it as an automatic recapitalization tool to mitigate systemic risk. The equity credits might be allowed to be reflected before conversion. However, there is no clear rule from FASB about contingent capital.

The impact on earnings volatility depends on the financial condition of the issuer or the financial industry. If the contingent capital is treated as debt before conversion and equity after conversion, the earnings volatility of the issuer before conversion will be the same as that for issuing traditional debt. However, upon conversion, a write-down of the issuer’s liability will certainly reduce the loss and therefore the earnings volatility. If the conversion option is separated from the host contract, the earnings volatility of the issuer before conversion tends to be more volatile compared to issuing a traditional bond. The mark-to-market value of the conversion option will be a major contributor to the volatility.

### **4.4 Tax Deductibility**

One of the key benefits of issuing contingent capital is the tax treatment which it is expected to receive. The interest payments of contingent capital are tax deductible considering the fact that contingent capital behaves like a debt instrument before conversion. Contingent capital and equity are still quite different given that contingent capital has limited upside while equity has unlimited upside. In addition, the contingent capital is brought in to reduce systemic risk and the cost of government bailout in a financial crisis. Because contingent capital has a combination of limited upside and potential loss absorbency, it makes more sense for it to be tax deductible.

Bolton and Samama (2011) mentioned that Lloyds Banking Group’s ECNs and Rabobank’s

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<sup>36</sup> European Commission, “IAS 32,” 10.

## *Understanding Contingent Capital*

Senior Contingent Notes are tax deductible.<sup>37</sup> Although both of the contingent capital instruments were issued since the financial crisis in 2008, the two issuers are under different financial conditions at issuance. Lloyds Banking Group had been bailed out by the government while Rabobank was in good financial conditions and the Senior Contingent Notes were oversubscribed. This indicates the likely treatment that contingent capital might receive, both in good times and in bad times.

Bolton and Samama (2011) also mention a possibility that the option premium as part of the coupon payments is not tax deductible and the movement of the fair value of the embedded option needs to be taxed as an income. Its complexity might make this unlikely. However, the IFRS is likely to require the debt component and the equity component to be separately reported under fair value basis. Therefore, there may still be a chance that the conversion option will be treated differently from the pure debt component.

### **4.5 Disclosure Requirement**

Due to the complexity of contingent capital, transparency is the key to its marketability. Rating agencies have expressed their positive view on this desired feature. Investors would also prefer securities with sufficient information about the issuer. Vagueness means higher required return and lower price of contingent capital instruments which will increase the cost of financing. The report publicized by Goldman Sachs emphasized more standardized bank disclosure as an important factor to make the objective triggers more credible.<sup>38</sup>

Not only is the disclosure of the contingent capital instrument itself necessary for transparency, but more detailed and timely disclosure of financial condition, business plan, and risk appetite is also needed for the success of contingent capital. The issuer needs to provide enough information to the potential investors so that they can assess the risk and return of the instruments. Without doing this, investors will not be able to make an informed decision and may be reluctant to invest.

### **4.6 Counterparty Risk Assessment**

Contingent capital instruments change the issuer's capital structure and risk-absorbing capability. For the issuer, there is no counterparty risk, as the price is paid at issue. However, the default risk profile of the issuer is changed when contingent capital is issued. Therefore, the counterparty risk of holding contingent capital and the ordinary fixed income securities without conversion options will be affected. In addition, the expected outcome of conversion may not be realized due to the behaviors of the investors and the issuer, as discussed in [Section 3.5](#). This makes the counterparty

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<sup>37</sup> Bolton and Samama, "Capital Access Bonds," 31-32.

<sup>38</sup> Goldman Sachs, "Contingent Capital," 4-8.



risk analysis even more complicated.

One straightforward approach is to rely on the credit rating given by the rating agencies. However, not all the contingent capital will be rated by rating agencies. The contingent capital instrument has to first meet the standard set out by the rating agencies. In addition, the credit rating may be unavailable or outdated when you need it to make the decision, especially in a stressed situation when the conversion is likely to happen soon.

An alternative approach that also relies on the market available information is the credit default swap spread. The impact of contingent capital on the default risk is expected to be reflected in the CDS spread. However, this information may not be available for certain issuers and is only available after the contingent capital instruments are issued.

Given the drawbacks of the approaches above, sometimes it is necessary to analyze the relationship between contingent capital and default risk in order to quantify the counterparty risk. Some papers have examples of quantifying the impact on default risk. Hilscher and Raviv (2011) showed analytically that contingent convertible bond financing can reduce the default probability compared to subordinated bond financing. The underlying logic is straightforward. The issuer will default if it cannot pay the coupon or redemption value of the subordinated bonds. However, that is not the case if a CoCo bond is used instead. The CoCo bond will be converted before the firm fails to pay the coupon and redemption value. Clearly, this argument is based on the assumption that the risk-taking behavior is the same in those two circumstances. If the issuer thinks that the introduction of CoCo bonds allows for a higher risk tolerance, the default risk could be higher due to the loss of the disciplinary power of debt instruments.

## **5. PRICING, VALUATION, AND RISK ASSESSMENT**

### **5.1 Pricing Models**

Contingent capital, as an innovative hybrid security, contains elements of both the debt and the equity. Generally, there are two types of models to price contingent capital.

- (1) The first type is based on the Merton (1974) model and the Black Scholes (1973) model. Sometimes it is called structural model. In the Merton model, the shareholder's value is considered as a call option on the firm's value with an exercise price equal to the value of the debt. By translating the trigger event into an equivalent value of the firm, Merton's model can be revised to model the probability of conversion using the equity call option model with a revised exercise price. Existing literatures about pricing contingent capital have more

## *Understanding Contingent Capital*

focus on this approach.

- (2) The second type is based on Duffie and Singleton (1999), which models defaults and values corporate bonds through the term structure of interest rate. Sometimes it is called reduced-form model. Unlike the Merton model, it does not explicitly consider the debt structure and the value of the firm at default, or, in other words, the exercise price of the call option. It models the default probability with a hazard rate influenced by exogenous market factors that are closely correlated with the firm value. To adjust for the feature of contingent capital, default intensity needs to be changed to trigger intensity which is the hazard function for the conversion. With Duffie and Singleton's approach, both default intensity and loss ratio can be set as a function of an exogenous variable, such as the stock price. Therefore, stakeholder behavior can be explicitly incorporated in the model. The model is also capable of including jumps for discontinuous information, such as capital rule changes in the diffusion process.

An extension of the first type is to include discontinuous jumps in modeling asset price. The classic Merton model assumes that the firm value follows the pattern of Geometric Brownian Motion. Geometric Brownian Motion is not good at explaining material value change over a short time period, which is a normal phenomenon for stock price. In addition, some contingent capital has its trigger event subject to ad hoc factors. As an example, for contingent capital with a trigger event based on capital adequacy ratio, discontinuous change in the value of the conversion option will happen when there is a change in capital rules, or business strategy, or when updated information is released, such as the capital position in a quarterly financial report. A compound Poisson Process is a common choice for the jump part in jump diffusion models used in the area of finance and risk management. It assumes an exponential distribution for the waiting time between jumps. The jump size follows a specified distribution itself. Sometimes, jump diffusion models are coupled with stochastic volatility, such as the Heston Model. This extra layer of flexibility can be used to take into account some stakeholder behavior such as shorting stocks before conversion.

This section discusses some of the models for contingent capital in existing literatures and the possible improvement.

### **CoCo Bonds**

Spiegeleer and Schoutens (2011) suggests a credit derivatives approach which determines the value of the credit spread on contingent convertible bonds by  $(1-\text{Recovery Rate}) \times \text{Trigger Intensity}$ . Recovery rate is the ratio of the share price at conversion to the conversion price. The trigger intensity is associated with the probability of triggering. Realizing the difficulty in modeling the capital adequacy ratio based on regulatory rules or the financial ratio based on accounting rules, the

## *Understanding Contingent Capital*

trigger event needs to be translated to an equivalent event such as the stock price dropping below a barrier. Utilizing the well-established digital barrier option pricing method, the probability of a trigger and the trigger intensity can be calculated. As the authors realized and mentioned in the paper, the shortcoming of a credit derivatives approach is that when the share price on the trigger date is very close to the conversion price, the recovery rate is almost one which would indicate that a contingent convertible bond is risk-free. In addition, a credit derivative approach does not consider the possibility that the coupon payment will cease if default event or a conversion happens. A low credit rating of CoCo bonds would indicate a high coupon rate, which has a big impact on the bond price. Equity derivative approach was suggested to take those missing factors into consideration. The CoCo bond can be valued as below.

- (1) Plain Vanilla Corporate Bond
- + (2) Knock-In Forwards between spot price and conversion price<sup>39</sup>
- (3) Down-and-in cash-or-nothing binary option on the coupon payments

Both the knock-in forwards and down-and-out cash-or-nothing binary option have stock as their underlying asset. Therefore, it is critical to determine the appropriate barrier for the stock price that is equivalent to the occurrence of the trigger event, at least approximately. However, how to translate the trigger event into an equivalent stock price and how to determine the trigger intensity is vague in Spiegeleer and Schoutens (2011). The approaches also neglect the possibility that without the conversion, the financial institute could go bankrupt directly, especially if the checking of the trigger event is not frequent.

A way of deriving the barrier for the stock price is to use the market price of existing deals. The authors illustrate the process of deriving an implicit barrier based on Lloyd's deals. If a similar CoCo bond exists in the market, the implicit barrier approach might be used as a reference point. However, there are several issues with this approach.

- (1) Even if the CoCo bonds have the same features, the financial condition, business profile, and the strategic plan could be quite different. Those factors have a big impact on the probability of conversion.
- (2) Until the CoCo bond market develops to be a much bigger one, lack of liquidity and transparency would impede us from adopting this approach.

But it is still valuable as a reference check for the price of the new issuance.

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<sup>39</sup> The knock-in forward will be effective if the trigger event for the CoCo bond happens.

## *Understanding Contingent Capital*

Takahashi et al. (2001) propose an approach of pricing convertible bond based on the Duffie and Singleton (1999) model for default risk. They suggest integrating the default risk and stock price by including the default intensity in the stock price diffusion process. It looks like a very promising candidate for valuing contingent convertible bond, as the trigger intensity could be highly correlated with the stock price, depending on the design of the CoCo bonds.

In a report by FitchSolutions, a structural approach which is more complicated than Merton's model is used to value a CoCo bond. The analytical first passage time model specifies a time dependent threshold which allows more flexibility in the calibration and pricing process. This model was used to value bonds with credit risk. It is modified to value contingent capital, considering both the probability of conversion and the probability of default. The paper also proposed a way to estimate the regulatory capital position based on the leverage ratio.

For contingent capital securities with a dual trigger design, the model could be more complicated. McDonald (2011) provided a pricing example of a dual trigger convertible bond based on the assumption that stock price and systemwide index follows correlated Geometric Brownian Processes with mean reversion. A simulation method is used to calculate the price of contingent capital securities. Historical volatility is used for the volatility parameters and the correlation. In practice, those assumptions might need forward-looking elements. In addition, a linear correlation might be too aggressive an assumption. As the conversion normally happens in a tail event, stock price and index value tend to move at a closer pace than in normal circumstances.

Bolton and Samama (2011) proposed the valuation methods of capital access bond (CAB). CAB is similar to traditional convertible bonds with the exception that the owner of the conversion option is the issuer, not the investor. The issuer also has the option to call the bond before maturity. The option premium for covering the cost of conversion option and call option can be determined using standard option valuation formula. However, the probability of default should be considered. The option premium will be unpaid if the issuer goes bankrupt. The conversion option premium before adjustment also needs to reflect a certain degree of default risk. This is because it is possible that the issuer may go bankrupt before the CAB is converted. Therefore, using an adjusted option price formula is not ideal for valuing CAB. A trinomial tree model was also illustrated by Bolton and Samama (2011). It is more rigorous than using standard option pricing formula as it models the dynamic process of stock price and the conversion.

Each type of the pricing models has its weakness. In structural models, one of the most critical parts is to determine the barrier for the stock price. For trigger events that are directly based on the stock price, it would not be an issue. However, for trigger events that are based on a capital

## *Understanding Contingent Capital*

adequacy ratio, it would be very difficult to have a reasonable estimate due to the managerial discretion, the regulatory change, and the time lag between the release of the capital report and the change of stock market.

Another thing to keep in mind when using structural models for pricing contingent capital is that the volatility parameters should be calibrated to appropriate target. Due to the non-flat volatility term structure, the implied volatility of an at-the-money equity put option could be quite different from that of an out-of-money equity put option. Given the level of the trigger point and financial condition of the issuer, an equity put option with a strike price close to expected equity price near conversion should be chosen as the calibration target. However, there may not be enough market information for out-of-money equity options in practice. It could be a major limitation of using structural models in such a situation.

On the other hand, reduced form models need to calibrate the hazard rate of conversion, which poses a big challenge as well. Selecting an appropriate state variable that the hazard rate has a high dependence on and figuring out the relationship between them is not an easy task.

In addition, without explicitly considering the cause and effect, some facts about the issuer, such as its capital structure, may not be appropriately priced in using reduced-form models. It may have a material impact on the price, considering that most of the issuers are large financial institutions with a diverse business and risk profile.

There are some areas that need further research. The price of contingent capital is sensitive to those factors.

- (1) Existing models often lack a framework that can explicitly quantify the impact of the stakeholders' behavior, such as the manipulation of the stock price ([Section 3.5](#)) and the multiple equilibria issue ([Section 3.6](#)).
- (2) The conversion event, similar to the default event, deals with the tail risk where market data normally are too sparse to be used for a credible calibration.
- (3) Depending on the design of contingent capital, it is possible that default can happen before the conversion option is exercised. It has not been explicitly and fully addressed in existing pricing models.
- (4) The impact of the issuer's debt structure on the price of contingent capital needs to be incorporated in the pricing model at a more granular level considering different seniorities of the debt.

- (5) New issuance of contingent capital may have an impact on the equity value due to the potential value transfer between shareholder and debt holder and the change in risk taking capability. How to incorporate this kind of change in the stock price in the pricing framework deserves further study.

### **Catastrophe Equity Put**

Catastrophe equity put (CEP) has been used by the insurance industry to transfer the negative impact of catastrophe event on its capital position. It gives the issuer the right to sell stocks to investors at a fixed price once the catastrophe loss exceeds the specified limit. Unlike CoCo bonds, where all the risks could lead to the occurrence of the trigger event, CEP depends on the joint movement of catastrophe losses and stock prices. In other words, the trigger event and the stock price are considered to be highly correlated for CoCo bonds, but that is not the case for CEP. Therefore, it is important to model the relationship between losses and stock price.

Cox and Pedersen (2004) introduced a framework where asset price follows the geometric Brownian model with additional downward jumps when there is a catastrophe event. The jump size is static regardless of the size of the catastrophe loss.

Jaimungal and Wang (2006) generalized the model introduced by Cox et al. (2004) with a stochastic interest rate and the downward jump size depending on the total loss. Unlike Cox et al. (2004), the losses are assumed to follow a compound Poisson process. Jaimungal and Wang (2006) also pointed out that the counterparty risk is not explicitly modeled and the homogenous Poisson process for the catastrophe events is not appropriate for risks with seasonality.

Lin and Chang (2007) made a further step. In the context of catastrophe losses, a constant expected arrival time is not an appropriate assumption. Instead of using a Poisson process, Lin and Chang (2007) proposed the Markov Modulated Poisson Process to model the arrival process of catastrophe events. The arrival process is assumed to follow a homogenous Markov chain which determines the state of the Poisson process. In different states, the arrival rate of catastrophe events could be quite different.

There are two practical issues to consider when using those models.

- (1) Both the compound Poisson process and Markov Modulated Poisson Process require the calculation of the cumulative distribution function of the n-fold convolution of losses in the

## *Understanding Contingent Capital*

valuation formula. Except for a few distribution types of the loss size,<sup>40</sup> there is no closed-form formula for calculating aggregate loss. However, there are other methods to compute the n-fold convolution, such as the numerical method and the method of moments.<sup>41</sup> But it requires either a loss of accuracy or a higher cost of computing resources and time.

- (2) The calibration of the loss size model is not an easy task. Historical data of the catastrophe loss and its resulting share price drop are helpful. But a clear picture of the current and future catastrophe risk exposure is necessary to get an up-to-date assumption for the distribution of the downward jump size.

### **A Stochastic Approach**

Some of the pricing models described are analytically tractable and some are not. In light of more powerful computational capabilities, a stochastic approach is another feasible approach. By specifying the models for interest rate, asset price, and catastrophic loss, one can simulate the asset price, the exercise of the conversion option, and the generated cash flows. The value of contingent capital can then be estimated by taking the average of the discounted values for all scenarios. There are two types of stochastic scenarios: risk-neutral scenarios and real-world scenarios. Market-consistent risk-neutral valuation uses risk-neutral scenarios as discount rates while adjusting the probability to match the average discount value with market value. Market-consistent real-world scenarios use the sum of risk-free rate and implied-risk premium as a discount rate. Theoretically, both risk-neutral scenarios and real-world scenarios can be used for market consistent valuation. But risk-neutral scenarios are preferred, as they are more practical for calibration. When using risk-neutral scenarios, only the average discount value is useful. The distribution implied from risk-neutral scenarios probability is not realistic. Real-world scenarios are used for other purposes. It provides us a picture of possible outcomes. The distribution of the outcome itself, and other risk measures, such as value at risk (VaR), and conditional tail expectation (CTE), are very important tools in capital management and risk-return analysis. Normally, the most common measure is Value at Risk (VaR) which is the value at a certain percentile of a distribution. For example, 95% VaR is the 95 percentile of the loss distribution. Sometimes for distributions that are heavily skewed, VaR may underestimate the tail risk, as it does not consider the magnitude of the loss in the tail. Conditional Tail Expectation (CTE), a.k.a Tail VaR, provides more comprehensive information

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<sup>40</sup> Jaimungal and Wang (2006) illustrated the analytical tractability when the loss size follows the Gamma distribution. Lin and Chang (2007) illustrated the analytical tractability when the loss size follows the lognormal distribution. Ma and Liu (2004) introduced an analytical scheme to compute the n-fold convolution of exponential-sum distribution functions.

<sup>41</sup> Lenzauer, "The n-Fold Convolution," 94-98.

## *Understanding Contingent Capital*

about the uncertainty in the tail. Combined with further modeling and understanding of practical accounting nature, such risk analysis would help the investors understand the downside risk and assist the issuers to assess the effectiveness of contingent capital in risk transfer. It can also help quantify the potential benefit of contingent capital under stress scenarios as an integrated part of plan sponsor's capital planning strategy.

### **Account for Illiquidity**

Assets that are less liquid usually have a higher yield to compensate for illiquidity, *ceteris paribus*. This is often the case for the corporate bond market, where substantial difference is present and the liquidity premium changes through the economic or business cycle. Contingent capital market is still under development and its cash flows are hard to perfectly replicate using existing liquid assets, due to the uncertainty of an embedded conversion option. Realizing the rise of liquidity premium of assets during the recent financial crisis, regulators are considering adding liquidity premium in the valuation of insurance liability as well.<sup>42</sup> Therefore, a liquidity premium is a key factor to consider in setting the price. In the models discussed above, liquidity has not been explicitly included in the pricing framework. The impact of illiquidity can be reflected in the pricing models by adding a liquidity premium to the interest rate. However, even for assets without the conversion option, it is not easy to quantify the liquidity premium. The asset yield in excess of the risk-free rate includes expected credit spread, unexpected credit spread, liquidity premium, cost of conversion option, taxation difference, and residual spread caused by market inefficiency such as information asymmetry.

At the current stage, it is hardly reliable to use the market data of existing contingent capital deals for estimating the liquidity premium, as the data are not sufficient and the terms of the contracts vary greatly. However, the corporate bond market has more data and there are many studies about how to disentangle liquidity premium from the total spread. It is practical to leverage on the liquidity premium of a similar corporate bond with the same credit rating as of contingent capital. Further adjustment can be applied based on the size of the issuance and estimated demand. The following methods may be used for estimating the liquidity premium for corporate bonds.

- (1) Market spread - model spread derived from structural models. The model spread is considered as the credit spread.
- (2) Market spread - CDS spread with the same maturity and credit rating.

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<sup>42</sup> CEIOPS, "Task Force Report," 3-12.



- (3) Illiquid bond return – liquid bond return with the same cash flows and credit risk.

## **5.2 Valuation Models and Assumption Setting**

Sometimes, pricing is considered as valuation at the issue date. The quantitative models used for pricing and valuation normally are the same. However, due to different purposes and the evolution of the market since the issuance, the parameters used may change greatly. Even for valuation, the assumption used depends on the role of the stakeholder and the purpose of the valuation. This is not something new that is created by contingent capital. It exists for all the complicated financial instruments that do not have a liquid market. This section focuses on the fair valuation of the contingent capital before conversion. Upon conversion, there will be a liability written off or additional equity, whose value may be determined by the market.

The fair value discussed here is the exit price that represents the price to be paid when the asset is transferred, or the price to pay when the liability is transferred. This is the type of fair value that is adopted by IFRS and U.S. GAAP. Several difficulties exist for the contingent capital valuation at current stage.

- (1) There is no liquid market for contingent capital right now. Therefore, the exit price is not readily available from the market.
- (2) Although there are some ways to dynamically hedge a few risks embedded in contingent capital, the hedging effectiveness is been questioned. The risk exposure could evolve quickly in stressed situation and the dynamic hedging program may not be able to offset the change quickly enough. Other types of risk may not be able to hedge at all, such as systemic risk. Those hard-to-hedge or non-hedgeable risks need to be considered when estimating the fair value.
- (3) The exposure to stakeholders' behavior adds an extra layer of complexity. The quantification of its impact is not a trivial task and it is hard to get consensus on the assumption and the conclusion.

There are several approaches that may be used for valuing financial instruments. However, due to the characteristics of contingent capital and its current market, not all of them are appropriate.

- (1) Using an up-to-date market price of the contingent capital instrument, which is likely to be unavailable and illiquid in the current market.
- (2) Using the market value of asset instruments that can replicate the payments of contingent capital. Due to the embedded conversion option and the stakeholders' behavior, which are

### *Understanding Contingent Capital*

hard to predict, it is difficult to find asset instruments in the market that can replicate the cash flows of contingent capital well in all situations.

- (3) Using the discounted value of the expected cash flows with a discount curve that includes the risk premium. This is also known as the actuarial approach. It is extensively used to calculate the value of the insurance business. However, it is not well equipped to value the asset instruments with embedded options.
  - (a) The life of the contingent capital instruments and its cash flows vary greatly among different financial conditions, due to the conversion option. It is difficult to calculate the appropriate expected cash flows. The cash flows projected under the best estimated assumption may not be a good estimate, as the impact of a conversion option is likely to be neglected or underestimated when it is out of money at the time of valuation.
  - (b) Since there is not enough active trading in current market, it is difficult to derive the risk premium from the market price. Subjective assumption has to be made and the discount value can hardly be the market consistent value.
- (4) An extension of the third approach is taking the average of the discounted values based on real-world stochastic scenarios. The discount factors or the state prices are calibrated to the market price of asset instruments, where possible. In practice, this approach is difficult due to the unyielding number of state prices that need to be determined, especially for a multi-period arbitrage free model. To estimate the market consistent value, risk-neutral scenarios are often used to calculate the non-arbitrage price.
- (5) Using the closed form formula where the discount rate is the risk-free rate and model parameters such as equity volatility are calibrated to market price of asset instruments. In this way, it can achieve a certain level of market consistency where liquid market is available. However, it is not easy to account for the impact of stakeholders' behavior.
- (6) Taking the average of the discount values of the cash flows which are projected and discounted using risk-neutral stochastic scenarios. The economic scenario models are calibrated to the market price of asset instruments, where possible. In addition, the impact of expected investor behavior can be reflected to a certain extent. For example, near the trigger point, the stock price may be depressed by selling the existing shares or short selling. To account for this, the conversion can be assumed to occur before the stock price reaches the conversion price.

Therefore, the closed-form valuation and stochastic risk neutral valuation are relatively more

## *Understanding Contingent Capital*

appropriate for valuing contingent capital instruments.

The models described in Section 5.1 can be used, but with adjusted parameters that reflect the change since the issue date. The major areas that require contemporary assumption are given below.

- (1) The economic assumption needs to be updated based on the then-current economic climate. It includes, but is not limited to, interest rates, credit spread, equity value and expected equity return.
- (2) For contingent capital that covers non-financial risks such as catastrophe risk, the assumption of the frequency and severity of the risk events also needs to be updated.
- (3) The financial condition of the issuer may also change and this could have a material impact on the value of contingent capital with a trigger event at institutional level. The probability of default or conversion is affected by the business strategy and outlook.
- (4) Regulatory changes sometimes have an impact on the probability of conversion for contingent capital as well. For example, for the conversion option based on the capital adequacy ratio, changes in the capital rules will directly affect the chance of conversion. Another example is the contingent capital with a discretionary trigger event. Changes in the goal or style of the regulators may also affect their willingness to trigger the conversion.
- (5) The volatility assumption of the equity return is also important, and the value of contingent capital is very sensitive to it. In most cases, the volatility term structure is not flat. Even if the volatility curve itself remains unchanged, the originally out-of-the-money conversion option could become in the money, and if that happens the volatility parameter would need to be updated.

In addition, the occurrence of conversion depends on many factors that cannot be fully controlled or hedged, such as the change in capital rules, business strategy, economic cycle, and business environment. For example, if a CoCo bond has a trigger event based on the regulatory capital adequacy ratio, the timing of the conversion and amount of payment can be affected by a change in the capital rule. The estimated value based on either closed-form valuation or stochastic risk-neutral valuation needs to be reduced to reflect those non-hedgeable risks.

A possible way to determine the amount of the adjustment is to calculate the cost of holding extra capital to cover the risk exposure. The loss can be projected annually, if a tail event related to the non-hedgeable risks happens. The amount of adjustment is the cost of capital rate  $\times$  present

value of estimated annual losses. This is an idea borrowed from the market consistent valuation of insurance liabilities. Cost of residual non-hedgeable risks (CRNHR),<sup>43</sup> a component of market-consistent embedded value (MCEV), uses this approach to estimate the cost due to the exposure to the non-hedgeable risks. If there is a probability associated with the tail event, such as a 1-in-200-year event, or 99.5 percentile of the loss distribution, the capital required in the tail event is in the form of 99.5% value at risk. A more conservative approach to quantify the risk is to use the average loss if it is greater than the 99.5 percentile loss.

The tail event used to quantify non-hedgeable risk, in most cases, is difficult to choose, not to mention assigning a probability. It could be a historical extreme event or a prediction of the future crisis. The associated probability could be based on historical data or predicative models.

## **5.3 Risk Assessment**

### **5.3.1 Greeks**

Greeks are used to measure the sensitivity of financial instruments to key drivers such as equity price, interest rate, volatility, and time. The sensitivity of contingent capital can be estimated by calculating Greeks using valuation models.

- (1) Delta ( $\Delta$ ) =  $\delta V / \square \delta S$ , where  $\delta V$  is the change in the value of contingent capital and  $\delta S$  is the change in the equity price. The embedded conversion option is highly related to the capital adequacy of the issuer or the whole industry. Therefore, contingent capital instruments, especially those with a fixed conversion price, are sensitive to the issuer's equity price if the trigger is based on an institutional level event, or the industry's equity index if the trigger is based on an industry level event.
- (2) Gamma ( $\Gamma$ ) =  $\delta^2 V / \square \delta S^2$  explains the convexity of the value with respect to the equity price. The secondary level impact is more material when the equity price moves to a level that the conversion option is close to be exercised.
- (3) Vega ( $\nu$ ) =  $\delta V / \delta \sigma$ , where  $\square \delta \sigma$  is the change in equity volatility. Higher volatility means higher value of the conversion option.
- (4) Rho ( $\rho$ ) =  $\delta V / \square \delta r$ , where  $\delta r$  is the change in interest rate. It measures the sensitivity to interest rate. Contingent capital acts like fixed income securities before conversion. The present value of future coupon payments and redemption/conversion value will change if discount rate changes.

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<sup>43</sup> CFO Forum, "Market Consistent," 5-6.

## *Understanding Contingent Capital*

Given the diversity of contingent capital designs, it is hard to estimate the Greeks using the same formula. One possible way to generalize the estimation of Greeks is to translate the conversion option to a financial derivative with equity as the underlying asset. Valuation models that are analytically tractable can be used to calculate the Greeks using a closed-form formula. Stochastic valuation models can also be used to estimate the Greeks by revaluating the contingent capital instrument under shocked scenarios. In some cases, economic variables are assumed to be interdependent. For example, in an economic recession, a bear equity market is likely to be coupled with low government bond yield. A stochastic model can build the relationship in the scenarios, and it would be a better choice than an analytic model if this kind of interdependency needs to be considered.

### **5.3.2 Contingent Capital Hedging**

Theoretically, the risks of contingent capital can be offset either by static hedging or by dynamic hedging. There have been extensive studies about replicating exotic options with plain vanilla options statically. As long as the contingent capital can be translated into a portfolio of financial instruments, static hedging techniques can be applied.

In a case when there is no market to short the replicating portfolio or the cost is too high, dynamic hedging is another choice. It sets up a hedging portfolio that can offset the sensitivity of the contingent capital. The hedging portfolio needs to be rebalanced as the sensitivity changes, which may be due to a market movement or simply the passage of time.

However, the hedging may not be as effective as expected. The basis risk for some contingent capital instruments may be high. For example, for the CoCo bonds with the trigger event based on the statutory capital adequacy ratio (CAR), the equity price may not be a perfect indicator of the CAR due to the complexity of the capital rules. In addition, the CAR may be reported quarterly while the equity price changes every day. The issuer may go bankrupt before the conversion has a chance to take place. Hedging strategies built for the “translated” contingent capital are vulnerable to basis risk.

In addition, hedging activities may have detrimental market impact. The investors of contingent capital hold a short position on the conversion option. If the conversion price is fixed, short selling of the issuer’s stock provides an efficient Delta hedge. This will drag down the equity price further. When the stock price drops, more shares need to be short sold as the delta of the put option increases, which in turn puts more pressure on the equity price.

### **5.3.3 Earnings Volatility and Capital Adequacy**

Investors of contingent capital need to consider the impact on their risk profile. Earning volatility

## *Understanding Contingent Capital*

may increase due to the embedded conversion option offered to the issuers. Their available capital might be reduced if the conversion price is greater than the spot price at conversion. The impact will directly show on the financial reports such as income statement and balance sheet. Therefore, it is necessary to project the possible outcomes under different real-world scenarios, either stress scenarios or stochastic scenarios. With a clear understanding about the distribution of the future gain/loss, the portfolio managers can make an informed decision on whether the risks are acceptable or if there is any risk mitigation action to take.

On the other hand, issuers of contingent capital would expect reduced earnings volatility and enhanced capital position upon conversion.

### **6. CASE STUDY**

In this section, we will go through the pricing, valuation, and risk analysis of a sample contingent capital instrument. It is hoped that the reader will gain some perspectives of the fundamental quantitative works required for analyzing contingent capital. Given the diversity in the features of contingent capital, the methods used in the case study may not be enough or appropriate for other types of the contingent capital but the principle will not deviate too much. Although there is some calibration involved in the case study, it is insufficient to ensure a reasonable and marketable price or value. The main purpose of the case study is to illustrate the model, the process and the Excel tool built with it. More detailed market research is required to come with appropriate model parameters.

The details of the contingent capital instrument example are given below.

Facts about CoCo Bond XYZ	
Issuer	ABC Insurance Company
Face Amount	\$10,000,000
Trigger Event	NAIC RBC Ratio $\leq 150\%$
Conversion Price (CP)	\$40 per share
Term of Contract (T)	10 years
Current Stock Price ( $S_0$ )	\$45 per share
Current RBC Ratio ( $RBC_0$ )	300%

*Understanding Contingent Capital*

Credit Rating	S&P BBB+	
BBB+ rated junior subordinated bond yield	7.2%	
Dividend Yield (d)	0%	
Credit Default Swap Curve for subordinated bond	Term	Rate (bps)
	1	124.9
	2	198.9
	3	262.5
	4	300.6
	5	311.8
	7	313.9
	10	305.0
Economic Assumption		
Risk Free Interest Rate <sup>44</sup> (r)	3.0%	
Equity Volatility ( $\sigma$ )	45%	
Recovery Rate for Junior Subordinated Bonds	40%	

## 6.1 Pricing

The task is to determine an appropriate and marketable coupon rate for CoCo bond XYZ.

A plain vanilla junior subordinated bond with the same credit rating as the CoCo bond has a yield of 7.2%. Since the conversion price is well above the likely stock price at the conversion, the exercise of the conversion option means a loss to the CoCo bond holders. Therefore, the required yield of CoCo bond XYZ needs to be higher than 7.2% in this example.

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<sup>44</sup> In the case study, liquidity premium is assumed to be accounted for in the risk-free interest rate, where appropriate. The determination of liquidity premium is discussed in Section 5 and is not illustrated here.

## Understanding Contingent Capital

CoCo bond XYZ has a trigger event linked to the NAIC RBC ratio. The distribution of future RBC ratio is difficult to model due to the complexity of the liability portfolio of insurance companies, unpredictable changes in capital rules, and the uncertainty of management actions. On the other hand, quantitative financial models explicitly project future stock price, interest rate, and credit spreads. To rely on those models, the relationship between the RBC ratio and those modeled economic variables need to be figured out. Two likely explanatory variables are stock price and credit default swap (CDS) rates. Assume that for ABC Insurance Company, the stock price is expected to be \$15 at conversion based on the historical data of RBC ratio and stock price, an expected capital rule change, and the next 5-year risk budgeting plan.

### The Spiegeleer and Schoutens (2011) credit derivative approach

The Spiegeleer and Schoutens (2011) credit derivative approach can be used to get a rough estimate of the CoCo bond yield. The probability of triggering during the term of the contract can be calculated using the valuation formula for down-and-in cash (at expiry)-or-nothing binary option<sup>45</sup> without discounting the payoff back to the valuation date.

$$p = \Phi(d_1) + \left(\frac{B}{S}\right)^{2\alpha} \Phi(d_2)$$

$$d_1 = \frac{\log(B/S) - \left(r - d - \frac{\sigma^2}{2}\right) \cdot T}{\sigma\sqrt{T}} \quad d_2 = \frac{\log(B/S) + \left(r - d - \frac{\sigma^2}{2}\right) \cdot T}{\sigma\sqrt{T}}$$

$$\Phi(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^x e^{-\frac{y^2}{2}} dy \quad \alpha = \frac{r - d}{\sigma^2} - \frac{1}{2}$$

Parameters	B (stock price at conversion)	S	T	R	d	$\sigma$
Value	15	45	10	3%	0%	45%

The probability of triggering during the life of the CoCo bond is estimated to be 61.3% based on the parameters listed in the table above. This indicates an intensity of 0.095 for the triggering based on the formulae given below. The recovery rate at conversion can be calculated as the ratio of the

<sup>45</sup> Rubinstein, Mark and Eric Reiner, "Unscrambling," 75-83.



### Understanding Contingent Capital

stock price at conversion and the conversion price. It is 37.5% (15/40) in the example.

$$\lambda = -\frac{\log(1-p)}{T}$$

$$\text{Credit spread of CoCo Bond XYZ} = \lambda \times (1-\text{Recovery Rate}) = 5.9\%$$

$$\text{Total yield of CoCo Bond XYZ} = \text{credit spread} + \text{risk free rate} = 8.9\%$$

### The Spiegleer and Schoutens (2011) equity derivative approach

With an explicit consideration of the time of the conversion and the stop of coupon payment upon conversion, equity derivative approach determines the price of the CoCo bond as below.

- (1) Plain Vanilla Bond Price with risk-free discounting
- + (2) Knock-In Forwards between spot price and conversion price<sup>46</sup>
- (3) Down-and-in cash-or-nothing binary option on the coupon payments

The value of knock-in forwards and the binary option on the coupon payments can be calculated based on the well-established pricing formula of binary options. Using the pricing formula given by Spiegleer and Schoutens (2011),<sup>47</sup> an annual coupon rate of 9.3% will make the price of CoCo bond XYZ equal to its face amount. This is different from the total yield of 8.9% derived using the credit derivative approach. As mentioned in Section 5, credit derivative approach neglects the impact of coupon payments and might generate an unrealistically low bond yield, especially when the recovery rate is high.

### Garcia and Pede (2011) analytical first passage time approach

The analytical first-passage time approach model enhances the Merton model by introducing a time-dependent barrier for default and a non-flat volatility term structure. Details about the model are provided in [Appendix B](#).

$$V_t = S_t + \hat{H}(t).$$

$$\text{Firm-value process:} \quad dV_t = rV_t dt + \sigma(t)V_t dW_t^Q$$

$$\text{Barrier:} \quad \hat{H}(t) = H e^{n-B \int_0^t \sigma^2(s) ds}$$

$$\text{Equity:} \quad S_t = P_t E_t \left[ \frac{(V_T - \hat{H}(T))^+ 1_{\{\tau > T\}}}{P_T} \right]$$

<sup>46</sup> The knock-in forward will be effective if the trigger event for the CoCo bond happens.

<sup>47</sup> Spiegleer and Schoutens, "Pricing Contingent," 2011, 24. It is also listed in APPENDIX B.

*Understanding Contingent Capital*

RBC ratio: 
$$RBC_t = g\left(\frac{V_t}{\hat{H}_t}\right) + \varepsilon_t$$

Model parameters B, H, and  $\sigma(t)$  are calibrated to credit default swap (CDS) spread, equity value, and capital adequacy ratio.

Parameters	B	H	$\sigma_1$	$\sigma_2$	$\sigma_3$	$\sigma_4$	$\sigma_5$	$\sigma_6$	$\sigma_7$
Value	0.03	0.7	15.0%	11.0%	12.0%	12.4%	11.6%	11.3%	11.2%

The CoCo bond price can be calculated using the following process.

- (1) Simulate the firm value and barrier.
- (2) Conversion time  $\tau_c$  is simulated based on the value of  $V_t/H_t$  compared to a threshold translated from the RBC trigger level.
- (3) If there is no conversion before bond maturity, the value is the same as the value of the plain vanilla bond with risk-free discount rate. If there is a conversion, it is calculated as the value of paid coupons and the value after conversion.
- (4) Take the average of the bond value across all scenarios.

With the following model setup, a CoCo bond with an annual coupon rate of 8.7% will sell at par.

Parameters	RBC Ratio Report Frequency	Bond Maturity	# of Scenario	Conversion Price	Value at Start	V/H threshold
Value	annual	10	1000	0.27	Firm: 1 Barrier: 0.7 Equity: 0.3	120%

More frequent capital adequacy reporting will lead to a lower CoCo bond price.

RBC Ratio Reporting Frequency	Annual	Semi-annual	Quarterly
Value	1.00	0.98	0.96

*Understanding Contingent Capital*

<b>95% Confidence Interval</b>	0.97 ~ 1.03	0.95 ~ 1.01	0.93 ~ 0.99
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If there is a strong belief that the death spiral will happen when the company approaches the trigger level, the model can be adjusted by increasing the asset volatility and assume there is only downward movement when V/H is close to the threshold. The impact of death spiral on the bond value is quite material based on the illustration given below.

<b>Investor Behavior</b>	No	Short Selling near Trigger Level*
<b>Value</b>	1.00	0.85
<b>95% Confidence Interval</b>	0.97 ~ 1.04	0.82 ~ 0.88

\* Downward movement and twice the calibrated volatility are assumed when V/H is below 125%.

If there is an expectation of some ad hoc changes before the CoCo bond matures, jumps can be added to both the firm value and barrier. The goal of adding the jump component is to incorporate the expectation of more stringent capital requirement in the near future and the management actions in reducing the resulting cost by adjusting business strategy and mitigating risks.

$$\text{Firm-value process: } V_t = V_0 \exp\left( rdt + \sigma(t)W_t^Q + \sum_{i=1}^{N_t} Y_i \right)$$

$$\text{Barrier: } \hat{H}(t) = He^{rt - B \int_0^t \sigma^2(s) ds + \sum_{i=1}^{N_t} Z_i}$$

N determines the number of jumps and it follows the Poisson process with parameter  $\lambda$

Y determines the shock size due to management actions. In this example, it is assumed to be positive but less than Z.

Z determines the shock size due to capital rule changes. In this example, it is assumed to be positive to account for more stringent capital requirement in the future.

For the sake of simplicity, the following parameters are used in the example. A compound Poisson process is simulated to determine both the number of jumps before bond maturity and the arrival time of jumps.

*Understanding Contingent Capital*

Parameters	$\lambda$	Fixed size of Y	Fixed size of Z	Equity Value at Start
Value	0.5 (expected one time in two years)	0.02	0.05	0.30

The value of CoCo bond is sensitive to those overall negative jumps.

Jumps	No	Compound Poisson Process with Fixed Shock Size*
Value	1.00	0.85
95% Confidence Interval	0.97 ~ 1.04	0.82 ~ 0.89

\* One in two years with an overall impact of 5.2% drops in equity value per time.

### The Duffie and Singleton (1999) Approach with Equity Price State Variable

Duffie and Singleton (1999) proposed a new approach to model financial instruments that are subject to default risk. The default-adjusted short-rate process was introduced which explicitly consider the default hazard rate and loss ratio. The beauty of this model framework is the capability of having a state dependent default hazard rate and loss-ratio process. For a CoCo bond, an ideal candidate of the state variable is the stock price, as the exercise of the conversion option and the value of payoff are correlated with the stock performance. The state process could also be a jump diffusion process which is flexible enough to model ad hoc changes. The following model set up is used in the case study.

Default-adjusted Discount Rate:  $R(t) = r(t) + Lh(S, t)$

Stock Price:  $S_t = S_0 \exp\left(r(t)dt + \sigma_s dW + \sum_{i=1}^{N_i} Y_i\right)$

### *Understanding Contingent Capital*

Value of Convertible Security: 
$$V_t = E_t^Q \left[ e^{-\int_t^T R(u)du} X + \int_t^T e^{-\int_t^u R(u)du} dC_s \right]$$

Conversion Hazard Rate: 
$$h(S, t) = \theta + \frac{\rho}{S_t}$$

Loss Ratio at Conversion: 
$$L = (1 - K / CP)$$

Notations:

X: Redemption Value

$C_t$ : Coupon Payment Process

CP: Conversion Price

$\sum_{i=1}^{N_t} Y_i$  : Jump Component that follows Compound Poisson Process with negative shock size.

K: Translated threshold for stock price at or below which the conversion option will be exercised.

The volatility parameter of equity price process can be calibrated using equity option market value. The jump component can be used to model expected future discontinuous changes. A translated threshold for equity price is used to approximate the trigger event. A fixed recovery rate is assumed as the translated threshold for equity price divided by the conversion price. This implicitly assumes that the exercise of the conversion option is continuous. In reality, stock price could drop well below the translated threshold before the occurrence of the trigger event. It can be compensated for by adjusting up the hazard rate for conversion. However, the key challenge of using this method is the calibration of the conversion hazard rate function. Due to the lack of liquidity in contingent capital market, it might be difficult to have something market consistent. A possible way of estimation is given below.

Step 1: Calibrate the parameters ( $\theta$  and  $\rho$ ) to the price of a plain vanilla bond without the conversion option;

Step 2: Estimate the probability of conversion before bond maturity, based on the translated threshold for equity price;

Step 3: Adjust  $\rho$  to be the estimated  $\rho$  in step 1  $\times$  probability of conversion/probability of default.

## Understanding Contingent Capital

With the following inputs and parameters, the CoCo bond is priced at par in this example.

K (estimated threshold for stock price)	Coupon Rate	Plain Vanilla Bond Yield	Hazard Rate Function		S	T	R	$\sigma$	Jump <sup>□</sup>	
			$\theta$	$\rho^{\square}$					$\lambda$	Size
15	8.7%	7.2%	0.035	1.46	45	10	3%	45%	0.5	0.05

Notes:

1. A  $\rho$  of 0.92 generates a model value of the plain vanilla bond price equal to its market value. The stock price process is used to approximate the probability of conversion and the probability of default by assuming that a stock price of \$15 or less leads to a conversion and a stock price of \$10 or less leads to a default.
2. One in two years with an overall impact of 5.2% drop in equity value per time.

### 6.2 Valuation

The valuation process is quite similar to pricing except that the economic environment and financial condition could be much different from those at the issue date. Since there are some non-hedgeable risks embedded in contingent capital, its market is not a complete market. Therefore, there is a need to deduct the cost of residual non-hedgeable risks (CRNHRs) from the value calculated using the pricing model. The way of calculating a market-consistent embedded value of insurance products can be borrowed to estimate the cost.

A common method used to estimate CRNHR is the Cost of Capital (CoC) approach.

$$CRNHR = \sum_{t=0}^{T-1} REC_t \times CoC \times v_{t+1} \times p_t$$

REC : Required Economic Capital for Non Hedgeable Risks

CoC : Cost of Capital

$v_t$  : Discount Factor at time t

$p_t$  : Survival Probability

$REC_0$  = shocked CoCo bond value under stress scenario - current CoCo bond value

$REC_t$  can be estimated as  $\alpha \times \text{Risk Driver}_t$

$\alpha = REC_0 / \text{Risk Driver}_0$

Continue with the pricing example of using the analytical first-passage time approach with annual RBC reporting frequency. The non-hedgeable risk to consider is a more stringent capital rule. The following jump component is used to represent the stress scenario.

### *Understanding Contingent Capital*

Parameters	$\lambda$	Fixed size of Y	Fixed size of Z	Equity Value at Start
Value	0.5 (expected one time in two years)	0.06	0.15	0.30

\* One in two years with an overall impact of 17.1% drops in equity value per time.

Under the stressed scenario, the model value of a CoCo bond becomes 0.657. The risk driver is set to be the price of a plain vanilla bond without the conversion option and assuming no default risk.

$\alpha$	CoC Rate	CRNHR	Adjusted CoCo Bond Price
25.9%	4%	0.09	0.91

When more than one non-hedgeable risk is considered, correlation among the risks needs to be quantified to reduce the aggregated required economic capital.

## 6.3 Risk Assessment

### Greeks

Greeks are used to illustrate the sensitivity of the CoCo bond value to economic variables or model assumptions. Using Garcia and Pede's (2011) analytical first-passage time approach, the estimated Greeks are given in the table below. A negative Gamma means that the second order impact of a drop in equity value on CoCo bond price is also negative. This is expected, as an equity price decrease will not only increase the probability of conversion but also push forward the timing of the conversion.

Scenario	Parameter			Bond Price			Greeks	Value
	Baseline	Up	Down	Baseline	Up	Down		
Equity Value	0.3	0.31	0.29	1.00	1.02	0.97	<b><math>\Delta</math>: Delta</b>	<b>2.6</b>
Interest Rate	3%	0.03	0.03	1.00	1.00	1.01	<b><math>\Gamma</math>: Gamma</b>	<b>-31.1</b>
Volatility		+ 1%	- 1%	1.00	0.95	1.05	<b><math>\rho</math>: Rho</b>	<b>-6.2</b>
							<b><math>v</math>: Vega</b>	<b>-4.8</b>

### Stochastic Analysis

For the investors, it is also useful to take a look at the distribution of the bond value and the worst possible outcome. On the other hand, the issuer would be interested to know how much capital relief it could gain from the conversion option and how it can offset the negative earnings in the stressed situation.

## Understanding Contingent Capital

Stochastic analysis with real-world scenarios can be used to look into the tail risk of investing in a CoCo bond and the benefit of issuing a CoCo bond at the tail event. It is also an appropriate framework for incorporating an expectation different from the market. In the following example, under some arbitrary real-world economic assumptions, the stock price, conversion time, and the loss of the investor at conversion are simulated and the outcomes at the tail are summarized. One thousand scenarios are used for illustration.

### Model Setup

Risk Free Rate:  $dr = \{\theta(t) - \alpha r(t)\}dt + \sigma_r dW_r$  (One Factor Hull White Model)

Stock Price:  $S_t = S_0 \exp\left(\mu(t)dt + \sigma_s dW_s + \sum_{i=1}^{N_i} Y_i\right)$

Expected Equity Return:  $\mu(S, t) = r(t) + \text{risk premium}$

Correlation of Diffusion Processes:  $\rho = \text{corr}(dW_r, dW_s)$

Conversion Time:  $\tau_c = \inf\{t \geq 0 \text{ s.t. } S_t \leq K\}$

Loss Ratio at Conversion:  $L(S, t) = 1 - \text{Min}(K, S_{\tau_c}) / CP$

#### Notations:

$CP$ : Conversion Price

$\sum_{i=1}^{N_i} Y_i$ : Jump Component that follows Compound Poisson Process with negative shock size.

$K$ : Translated threshold for stock price at or below which the conversion option will be exercised.

The following table lists major parameters used in the example.

K (estimated threshold for stock price)	Coupon Rate	Plain Vanilla Bond Yield	One Factor Hull White		S	T	R	$\rho$	$\sigma$	Jump <sup>□</sup>	
			$\alpha$	$\sigma$						$\lambda$	Size
15	8.7%	7.2%	0.9	1.5%	45	10	3%	5%	45%	0.5	0.05

Notes: One in two years with an overall impact of 5.2% drop in equity value per time.

Value of tail risk measures are given below. A higher loss ratio for the investors means a greater reduction of debt obligation for the issuer.



*Understanding Contingent Capital*

<b>Variables</b>	<b>Stock Price at Conversion</b>	<b>Conversion Time</b>	<b>Loss Ratio at Conversion</b>
<i>Risk Measures</i>	<i>Left Tail</i>	<i>Left Tail</i>	<i>Right Tail</i>
<b>95% VaR</b>	9.46	3.00	76%
<b>95% CTE</b>	8.14	2.30	80%
<b>99% VaR</b>	7.22	2.00	82%
<b>99% CTE</b>	6.53	1.60	84%
<b>99.5% VaR</b>	6.92	2.00	83%
<b>99.5% CTE</b>	5.94	1.20	85%

Figures 1-3 illustrate the probability density functions of conversion time, stock price at conversion, and loss ratio, given that the conversion happened.

**Figure 1: Histogram of Conversion Time Given It Happens**

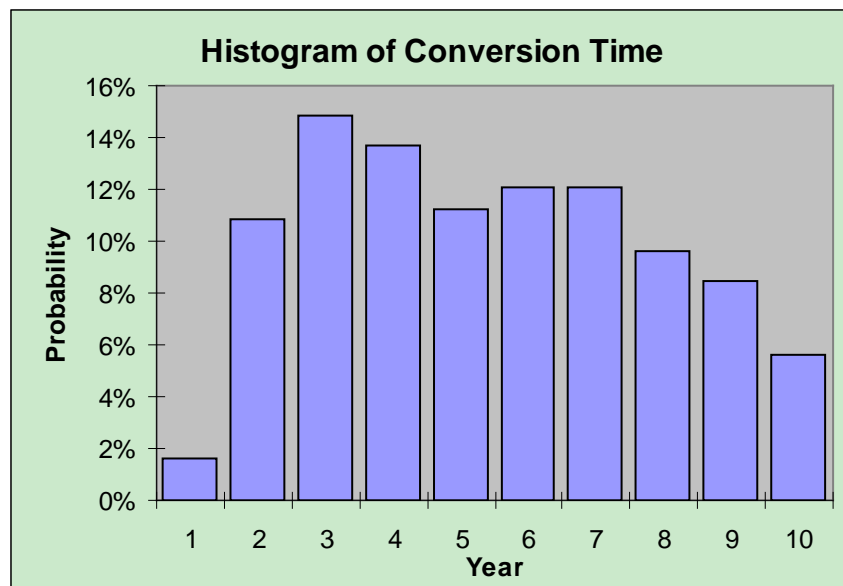


Figure 2: Histogram of Stock Price at Conversion

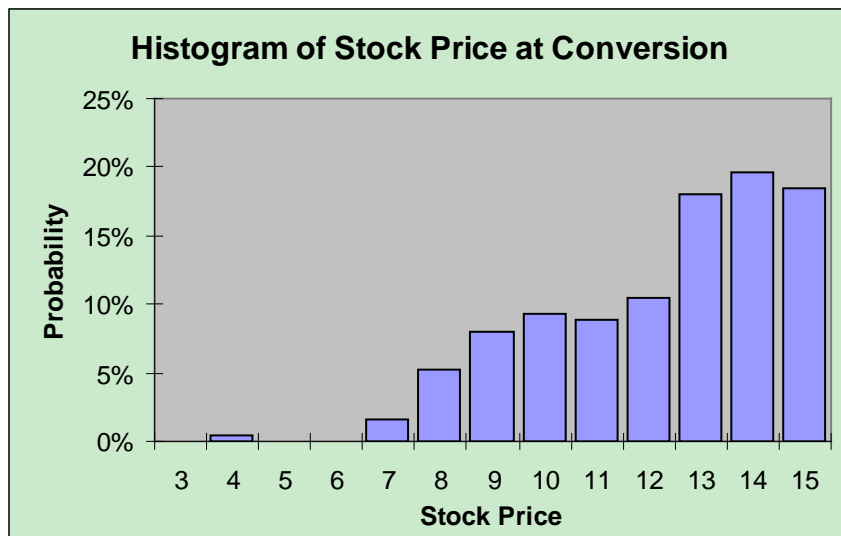
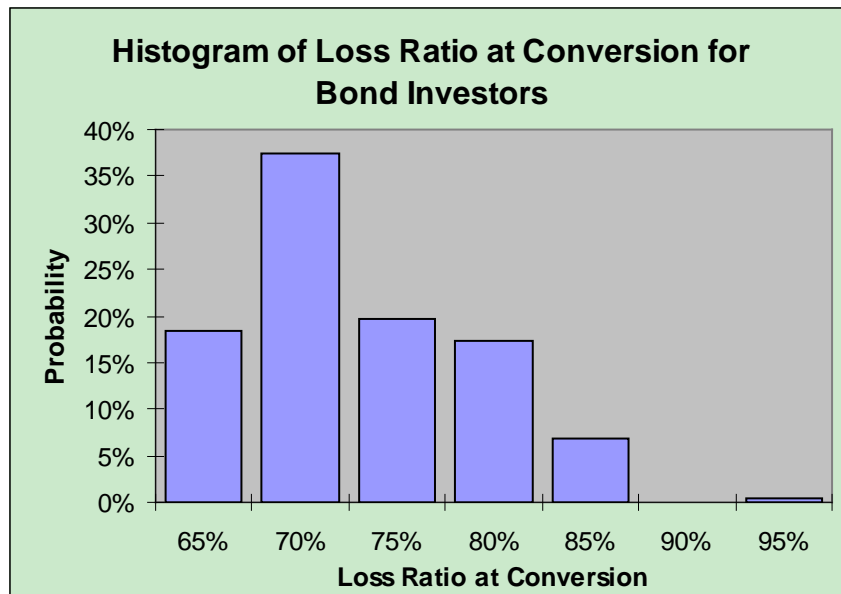


Figure 3: Histogram of Investor's Loss Ratio at Conversion



Based on the purpose of the risk analysis, it can be extended to quantify the impact on earnings volatility and capital at risk, based on a specified financial reporting framework and capital rules.

## **7. CONCLUSION**

Contingent capital is considered as a promising candidate for improving the risk tolerance of the financial industry and reducing the cost of the financial crisis paid by the taxpayers. Compared to subordinated debt instruments, contingent capital increases the capability of absorbing loss. Compared to equity, contingent capital has a lower cost of capital before conversion. Despite the doubts about its success, it is welcomed by the regulators and there have been many proposals of the appropriate design of contingent capital instruments.

However, there is still a long way to go before contingent capital can be widely accepted and utilized.

- (1) The trigger event has so many possibilities that choosing an appropriate design is not an easy task. A small change of the feature may have a material impact on its effectiveness of reducing the chance of default. There remains a lot to discover and test in the market.
- (2) Closely related to the trigger event, the behavior of the stakeholders needs more analysis. They include both rational behaviors, and irrational behaviors such as panic. Some behaviors may drag the issuer down further near conversion instead of helping as intended. They need to be fully understood and the potential impact needs to be quantified.
- (3) The complexity and uncertainty of contingent capital make it difficult for pricing, valuation, and risk assessment. Although there are some models for analyzing contingent capital, they are highly data driven. Those garbage-in garbage-out models will not be very useful before a liquid market emerges for contingent capital. How to set a fair price is more of an art than a math problem.

Hopefully after those issues are solved, contingent capital will be instrumental in reducing the systemic risk of the industry and default risk of financial institutions without incurring too much additional cost of capital for investors.

### **Acknowledgment**

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### **Supplementary Material**

A spreadsheet is built to illustrate the pricing, valuation, and risk analysis for contingent capital. It is used intensively  
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in the case study.

## APPENDIX A. QUICK GUIDE FOR CONTINGENT CAPITAL QA TOOL

CONTINGENT CAPITAL QA TOOL is a spreadsheet model built to illustrate the pricing, valuation, and risk analysis for contingent capital. It is capable of pricing/valuing certain types of contingent capital instruments using closed form solution and stochastic approach. Model calibration and risk analysis are also included. It could serve as a good education material to understand contingent capital and risk quantification. All the quantitative results used in the case study are generated using this tool.

In order to use this tool properly, the user needs to enable the macros after the spreadsheet is opened. Most of the calculation functions are built using VBA. In addition, the user needs to accept the disclaimer statements before using the tool. The spreadsheet has most of its input cells green colored and output cells blue colored. Tab “ReadMe” provides descriptions of the functionality, output, and new functions built with VBA.

The following models have been built in the tool.

- (1) Spiegeleer et al. (2011) Credit Derivative Approach<sup>[47]</sup>: Tab “S&S Credit Approach”;
- (2) Spiegeleer et al. (2011) Equity Derivative Approach<sup>[47]</sup>: Tab “S&S Equity Approach”;
- (3) Garcia and Pedraza (2011) Analytical First Passage Time Approach<sup>[27]</sup>: Tab “AFPT”;
- (4) Duffie and Singleton (1999) Approach<sup>[15]</sup> with equity price as the state variable<sup>[50]</sup>: Tab “ADS”;
- (5) Risk Analysis such as VaR and Greeks: Tab “Risk Analysis”.

## APPENDIX B. MORE FORMULAS USED IN THE CASE STUDY

### Spiegeleer and Schoutens (2011) equity derivative approach<sup>48</sup>

CoCo Bond Price

- = (1) Plain Vanilla Bond Price with risk free discounting
- + (2) Knock-In Forwards between spot price and conversion price
- (3) Down-and-in cash (at expiry)-or-nothing binary option on the coupon payments

$$(1): \text{price } N \cdot e^{-rT} + \sum_{i=1}^m c_i \cdot e^{-r t_i}$$

$$(2): \text{payoff} = N/CP \cdot (S(\tau) - CP) \text{ at time } \tau \text{ if for the first time } \tau < T_i, S(\tau) < B \\ = 0 \text{ if for all } \tau < t_i, S(\tau) > B$$

It is approximated as the payoff of

- (a) down-and-in asset-or-nothing call

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<sup>48</sup> Spiegeleer and Schoutens, “Pricing Contingent,” 2011, 24.

- (b) down-and-in asset-or-nothing put
- (c) down-and-in asset(at expiry)-or-nothing

The only difference is in the payoff time. For a CoCo bond, it happens at the time of conversion. For (a), (b), and (c), the payoff happens at time T. When the issuer is in a financial distress, the chance of the conversion is high and the conversion is expected to be early if it happens. In this case, the price of using (a)-(b)-(c) may not be a good estimator and may need to be adjusted to avoid an underestimation of CoCo bond price.

$$(2): \text{price } \frac{N}{CP} \left\{ \begin{array}{l} S \cdot e^{-qt} \cdot \left(\frac{B}{S}\right)^{2\lambda} \Phi(y_1) + S \cdot e^{-qt} \cdot \Phi(-x_1) \\ - K \cdot e^{-rT} \left[ \Phi(-x_1 + \sigma\sqrt{T}) + \left(\frac{B}{S}\right)^{2\lambda-2} \Phi(y_1 - \sigma\sqrt{T}) \right] \end{array} \right\}$$

$$(3): \text{payoff} = c_i \text{ if for all } \tau < t_i, S(\tau) > B \\ = 0 \text{ if for some } \tau < t_i, S(\tau) < B$$

$$\text{price} \sum_{i=1}^m c_i \cdot e^{-rt_i} \cdot \left[ \Phi(-x_{1i} + \sigma\sqrt{t_i}) + \left(\frac{B}{S}\right)^{2\lambda-2} \Phi(y_{1i} - \sigma\sqrt{t_i}) \right]$$

$B$  : Stock price at conversion       $CP$  : Conversion price  
 $T$  : Term of CoCo bond       $t_i$  : ith coupon payment time  
 $c_i$  : ith coupon payment amount       $N$  : Face amount  
 $m$  : # of future coupon payments till time T

$$x_1 = \frac{\log\left(\frac{S}{B}\right) + \lambda T}{\sigma\sqrt{T}} \quad y_2 = \frac{\log\left(\frac{B}{S}\right) + \lambda T}{\sigma\sqrt{T}}$$

$$x_{1i} = \frac{\log\left(\frac{S}{B}\right) + \lambda t_i}{\sigma\sqrt{t_i}} \quad y_{2i} = \frac{\log\left(\frac{B}{S}\right) + \lambda t_i}{\sigma\sqrt{t_i}}$$

$$\Phi(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^x e^{-\frac{y^2}{2}} dy \quad \lambda = \frac{r - d + \sigma^2/2}{\sigma^2}$$

### Garcia and Pedre (2011) analytical first passage time approach

The following model and calibration method are applied in the case study. They are based on Garcia and Pedre (2011), either identical or with a slight difference.

**Model Setup**

Firm-value process:  $dV_t = rV_t dt + \sigma(t)V_t dW_t^Q$

Barrier:  $\hat{H}(t) = H e^{rt - B \int_0^t \sigma^2(s) ds}$

Equity:  $S_t = P_t E_t \left[ \frac{(V_T - \hat{H}(T))^+ 1_{\{\tau > T\}}}{P_T} \right]$

$V_t = S_t + \hat{H}(t)$

Survival probability:  $P(\tau > T) = \Phi(d_1) - \left(\frac{H}{V_0}\right)^{2B-1} \Phi(d_2)$

CDS model spread:  $S^{T_0, T_N}(t) = \frac{(1-R) \sum_i \frac{P_t}{P_{T_i}} (P(\tau > T_{i-1}) - P(\tau > T_i))}{\sum_i \frac{P_t}{P_{T_i}} (T_i - T_{i-1}) \left( P(\tau > T_i) + \frac{1}{2} (P(\tau > T_{i-1}) - P(\tau > T_i)) \right)}$

Notations:

$d_1 = \frac{\log \frac{V_0}{H} + \frac{2B-1}{2} \int_0^T \sigma(s)^2 ds}{\left( \int_0^T \sigma(s)^2 ds \right)^{1/2}}$

$d_2 = d_1 - \frac{2 \log \frac{V_0}{H}}{\left( \int_0^T \sigma(s)^2 ds \right)^{1/2}}$

$\tau = \inf \{ t \geq 0 \text{ s.t. } V_t \leq \hat{H}(t) \}$

$P_t = e^{-rt}$  zero coupon bond price with term t

It is also assumed that NAIC RBC Ratio can be estimated based on the value of  $V_t$  and  $H_t$ .

$RBC_t = f\left(\frac{V_t}{\hat{H}_t}\right) + \varepsilon_t$ , where  $f$  is a monotonically increasing function.

Equity price  $E_t = f(V_t, t)$  follows the following partial differential equation and boundary conditions.

$\partial_t f = -\frac{1}{2} \sigma(t)^2 x^2 \partial_{xx} f - rx \partial_x f + rf, t \in (0, T) \text{ and } x \in R_+$

$f(x, T) = (x - \hat{H}(T))^+, x \in R_+$

$f(x, t) = 0, 0 \leq x \leq \hat{H}(t), t \in (0, T)$

$x = V_t$

To transform the boundary condition  $f(x, t) = 0, 0 \leq x \leq \hat{H}(t), t \in (0, T)$  to a fixed one, let  $E_t = f(V_t, t) = f^*\left(\frac{V_t}{\hat{H}(t)}, t\right) = f^*(x^*, t)$ . It then follows the following partial differential equation and boundary conditions.

$$\partial_t f^* = -\frac{1}{2}\sigma(t)^2 x^{*2} \partial_{x^* x^*} f^* - \left( rx^* - x^* \frac{\hat{H}'}{\hat{H}} \right) \partial_{x^*} f^* + rf^*, t \in (0, T) \text{ and } x^* \in R_+$$

$$f^*(x^*, T) = \hat{H}(T)(x-1)^+, x^* \in R_+$$

$$f^*(x^*, t) = 0, 0 \leq x^* \leq 1, t \in (0, T)$$

### Calibration Process

Parameters:  $H, B, \sigma(i), i = 1$  to  $M$

Targets: CDS spreads, equity price, and NAIC RBC ratio.

$$\text{Step 1: } RBC_0 = g\left(\frac{V_0}{\hat{H}_0}\right) \Rightarrow H$$

$$\text{Step 2: Minimize } D = \sum_{i=1}^M (\text{CDS model spread} - \text{CDS market spread})^2 \Rightarrow \sigma(i), i = 1 \text{ to } M$$

$$\text{Step 3: } E_t \Rightarrow B$$

Return to Step 2 if D is greater than the tolerance level of error

This method does not guarantee a global minimum being found and different guess of initial values need to be tried. Adjusted Levenberg-Marquardt algorithm is used for Step 2.

### CoCo Bond Price

The CoCo bond price can be calculated by simulating the conversion time  $\square$  first, calculating the value using the formulae given below, and then taking the average across the scenarios.

$$CBP(t, T) = 1_{\{\tau_c > T\}} BP(t, T) + 1_{\{\tau_c < T\}} \left( CP(t, \tau_c) + \frac{E_{\tau_c}}{CP} P(t, \tau_c) \right)$$

Where

CBP(t,T): CoCo bond price at time t with bond maturity at time T.

BP(t,T): Risk free bond price at time t with bond maturity at time T.

CP(t,  $\tau_c$ ): The value of coupon payments at time t with payments until time  $\tau_c$ .

P(t,T): Zero coupon bond price at time with bond maturity at time T.

CP: Conversion price.

$E_{\tau_c}$ : Stock price at conversion.

$\square$ : Conversion time.

Assume the RBC ratio threshold is  $RBC^*$ . The corresponding ratio of firm value to the barrier is  $g^{-1}(RBC^*)$  at or below which the conversion is triggered.  $g^{-1}$  is the inverse function of  $g$ . Under each scenario,  $\square$  is determined as the first time  $V_t \leq g^{-1}(RBC^*)$  or never.

**One-factor Hull White Model<sup>49</sup>**

$$dr = (\theta(t) - \alpha r)dt + \sigma dz$$

The mean of the short rate  $r$  reverts to  $\theta(t)/\alpha$  at rate  $\alpha$ .

The following stochastic process for  $R(t)$  with annual step is implemented to generate stochastic short rates for stochastic risk analysis.:

$$R(t+1) = bR(t) + \theta_t + \sigma_d \varepsilon_t$$

Auto Correlation:  $b=e^{-\alpha}$

$$\text{Discrete Volatility Parameter: } \sigma_d = \frac{\sigma(1-e^{-\alpha})}{\alpha} \sqrt{\frac{1-e^{-2\alpha}}{2\alpha}}$$

Random Shock:  $\varepsilon_t \sim N(0,1)$

$R(t+1)$  follows normal distribution  $N(\theta_t + bR(t); \sigma_d^2)$  given a known  $R(t)$

$$R(T) = b^{T-t} R(t) + \sum_{k=t}^{T-1} b^{T-1-k} (\theta_k + \sigma_d \varepsilon_k)$$

Probability distribution of  $R(T)$  at time  $t$  is a normal distribution.

$$\text{Mean: } R(T) = b^{T-t} R(t) + \sum_{k=t}^{T-1} b^{T-1-k} \theta_k$$

$$\text{Variance: } \text{Var} \left( \sum_{k=t}^{T-1} b^{T-1-k} \sigma_d \varepsilon_k \right) = \sigma_d^2 \left( \frac{1-b^{2(T-t)}}{1-b^2} \right)$$

Under risk-neutral valuation, the bond price is calculated as

$$P(t, T) = \mathbf{E}_t^* \left[ \exp \left\{ - \sum_{k=t}^{T-1} R(k) \right\} \right]$$

$$\sum_{k=t}^{T-1} R(k) = \sum_{k=t}^{T-1} \left( b^{k-t} R(t) + \sum_{l=t}^{k-1} b^{k-1-l} (\theta_l + \sigma_d \varepsilon_l) \right)$$

$$= \left( \frac{1-b^{T-t}}{1-b} \right) R(t) + \sum_{l=t}^{T-2} \left( \frac{1-b^{T-l-1}}{1-b} \right) (\theta_l + \sigma_d \varepsilon_l)$$

Bond price can be written as follows.

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<sup>49</sup> Hull, J. and A. White: "One-Factor Interest Rate," 235-254. This section describes the details of One-factor Hull White interest rate model that are used for the case study.



$$P(t,T) = \mathbf{E}_t^* \left[ \exp \left\{ - \left( \frac{1-b^{T-t}}{1-b} \right) R(t) - \sum_{l=t}^{T-2} \left( \frac{1-b^{T-l-1}}{1-b} \right) (\theta_l^* + \sigma_d \varepsilon_l) \right\} \right]$$

$$= \exp \{ -B(T-t)R(t) + A(t,T) \}$$

$$B(S) = \left( \frac{1-b^S}{1-b} \right)$$

$$A(t,T) = - \sum_{l=t}^{T-2} \left( \frac{1-b^{T-l-1}}{1-b} \right) \theta_l^* + \frac{1}{2} \sigma_d^2 C(T-t-1)$$

$$C(S) = \frac{1}{(1-b)^2} \left( S - 2b \left( \frac{1-b^S}{1-b} \right) + b^2 \left( \frac{1-b^{2S}}{1-b^2} \right) \right)$$

Term structure of interest rates (zero's) at time t is given by solving  $P(t,T) = \exp \{ -Z(t,T)(T-t) \}$ :

$$Z(t,T) = \frac{-\ln P(t,T)}{T-t}$$

$$= \left( \frac{B(T-t)}{T-t} \right) R(t) - \left( \frac{A(t,T)}{T-t} \right)$$

### Model Calibration

Interest rate model parameters  $\theta_t, t = 0,1,2,\dots$  need to be calibrated to the initial yield curve. It can be achieved by solving the following function.  $Z(0,T)$  is the T-year zero rate at time zero.

$$-Z(0,T)T = - \sum_{l=0}^{T-2} \left( \frac{1-b^{T-l-1}}{1-b} \right) \theta_l^* + \frac{1}{2} \sigma_d^2 C(T-1) - B(T)R(0)$$

This equation can be solved iteratively. For  $T=2$ ,

$$\theta_0^* = Z(0,2)2 + \frac{1}{2} \sigma_d^2 C(1) - B(2)R(0)$$

The values for  $\theta_1^*, \theta_2^*$ , etc. can be found for  $T=3,4,\dots$

$$\theta_{T-2}^* = Z(0,T)T - \sum_{l=0}^{T-3} \left( \frac{1-b^{T-l-1}}{1-b} \right) \theta_l^* + \frac{1}{2} \sigma_d^2 C(T-1) - B(T)R(0)$$

Market instruments such as cap/floor and swaption can be used to calibrate the volatility parameters. Given the analytical tractability for the one-factor Hull White model, it is relatively easy to calibrate the parameters using either closed form formula or trinomial tree model<sup>50</sup>.

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### Abbreviations and notations

Collect here in alphabetical order all abbreviations and notations used in the paper

AOF, ancillary own fund	BCBS, Basel Committee on Banking Supervision
CAB, capital access bond	CAR, capital adequacy ratio
CEP, catastrophe equity put	CCC, contingent capital certificates
CoCo bond, contingent convertible bond	CRD, capital requirements directive
CRNHR, cost of residual non hedgeable risks	CTE, conditional tail expectation
DTI, deposit-taking institution	FASB, Financial Accounting Standards Board
FSB, Financial Stability Board	GSIB, global systemically important bank
IAS, International Accounting Standards	ILWs, industry loss warranties
IFRS, International Financial Reporting Standards	MCEV, market consistent embedded value
MCR, minimum capital requirement	NVCC, non-variability contingent capital
OSFI, Office of the Superintendent of Financial Institutions Canada	RoE, return on equity
SCR, solvency capital requirement	SIFI, systemically important financial institution
VaR, value at risk	VBA, Visual Basic Application

### Biography of the Author

**Kailan Shang** is a pricing actuary at Manulife Financial in Canada. Before that, he worked in the area of financial risk management and risk analytics in AIA. Years of actuarial and risk management experience has allowed him to get a broad exposure in the fields of economic capital, market-consistent embedded value, financial engineering, dynamic management options and policyholder behavior modeling, product development and management, financial reporting, dynamic solvency testing, and the like.

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