BACHELOR'S THESIS

A Valuation Concept for Coco Bonds

Author
Sina Öfinger
09-608-019
Dufourstrasse 153
9000 St. Gallen
sina.oefinger@student.unisg.ch

Submitted to

Prof. Dr. Karl Frauendorfer
Institute for Operations Research and Computational Finance

May 21, 2012
“Requiring installation of automatic sprinkler systems reduces the probability that a building will burn to the ground, but does not eliminate that possibility. [However,] having these systems, like having cocos on … the balance sheet of big financial institutions, … lowers the cost of fire insurance, or [– in the case of cocos –] the taxpayer cost of the government’s implicit too-big-to-fail guarantee.”

George M. von Furstenberg
J.H. Rudy Professor Emeritus of Economics at Indiana University, Bloomington

“They [CoCos] are a reasonable canary in the coalmine, a good proxy for the credit markets’ perception of the banks and also that of their sovereign, …”

Satish Pulle
Manager of European Credit Management’s new ECM Financials Fund

---

1 Von Furstenberg, 2011, p. 27.
Content

List of Tables ........................................................................................................ III

List of Figures ........................................................................................................ IV

1 Introduction ........................................................................................................ 1
   1.1 Motivation ........................................................................................................ 1
   1.2 Thesis structure ............................................................................................... 2

2 Contingent Convertible Bonds .......................................................................... 3
   2.1 Definition ......................................................................................................... 3
   2.2 Categorization of Contingent Convertible Capital ........................................ 4
   2.3 The Regulatory angle ..................................................................................... 6

3 Elements of Contingent Convertible Bonds .................................................... 8
   3.1 The Trigger ...................................................................................................... 8
      3.1.1 Bank-specific trigger .................................................................................. 9
         3.1.1.1 Capital ratio-based trigger ................................................................. 11
         3.1.1.2 High- versus low-trigger Cocos ....................................................... 12
         3.1.1.3 Market-based trigger ..................................................................... 15
      3.1.2 Systemic trigger .................................................................................... 18
      3.1.3 Dual Trigger .......................................................................................... 21
   3.2 Conversion terms ........................................................................................... 23
      3.2.1 Fixed value conversion .......................................................................... 25
      3.2.2 Fixed number conversion ..................................................................... 29

4 The Model .......................................................................................................... 32
   4.1 The original model ......................................................................................... 33
      4.1.1 Rock-bottom spreads ........................................................................... 34
      4.1.2 Input parameters .................................................................................... 34
         4.1.2.1 Cash flows and rating migration .................................................... 35
         4.1.2.2 The Sharpe ratio ......................................................................... 37
      4.1.3 Computing risk bottom spreads ............................................................ 38
   4.2 The adjusted model ....................................................................................... 45
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.2.1</td>
<td>Conversion</td>
<td>46</td>
</tr>
<tr>
<td>4.2.2</td>
<td>Callability</td>
<td>51</td>
</tr>
<tr>
<td>5</td>
<td>Pricing financial Cocos</td>
<td>53</td>
</tr>
<tr>
<td>5.1</td>
<td>Calibrating the model</td>
<td>53</td>
</tr>
<tr>
<td>5.2</td>
<td>Rock-bottom vs. market spreads</td>
<td>58</td>
</tr>
<tr>
<td>5.3</td>
<td>Model critics</td>
<td>59</td>
</tr>
<tr>
<td>6</td>
<td>Conclusion</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td>References</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>Abbreviations</td>
<td>VIII</td>
</tr>
<tr>
<td></td>
<td>Appendices</td>
<td>IX</td>
</tr>
<tr>
<td></td>
<td>Appendix 1</td>
<td>IX</td>
</tr>
<tr>
<td></td>
<td>Appendix 2</td>
<td>IX</td>
</tr>
<tr>
<td></td>
<td>Appendix 3</td>
<td>XII</td>
</tr>
<tr>
<td></td>
<td>Appendix 4</td>
<td>XIII</td>
</tr>
<tr>
<td></td>
<td>Appendix 5</td>
<td>XIV</td>
</tr>
<tr>
<td></td>
<td>Declaration of Authorship</td>
<td>XV</td>
</tr>
</tbody>
</table>
List of Tables

Table 1: Different forms of convertible capital ................................................................. 5
Table 2: Different forms of contingent capital ................................................................. 6
Table 3: Characteristics of bank-specific triggers ......................................................... 10
Table 4: Low vs. high trigger contingent capital ......................................................... 13
Table 5: Characteristics of systemic triggers ............................................................... 19
Table 6: Characteristics of dual-triggers ...................................................................... 21
Table 7: Characteristics of different conversion options ............................................. 24
Table 8: Characteristics of fixed value conversion ....................................................... 26
Table 9: Characteristics of a fixed number conversion ................................................. 30
Table 10: Average one-year Transition Matrix (1981-2011) - Financial institutions ...... 36
Table 11: Basic model input parameters ................................................................. 38
Table 12: Rock-bottom spreads for a financial bond with different maturities .......... 44
Table 13: Capital ratio rating adjustments .............................................................. 47
Table 14: Reduced vs. fixed conversion value rbs ..................................................... 50
Table 15: Credit Suisse T2 BCN Terms & Conditions ............................................. 53
Table 16: CS model input parameters ........................................................................ 56
Table 17: UBS T2 SN Terms & Conditions ............................................................... 56
Table 18: UBS model input parameters ................................................................. 58
Table 19: Probabilities for capital ratio triggers ..................................................... 60
Table 20: Rbs sensitivity with respect to interest rate changes .................................. IX
Table 21: Rbs sensitivity with respect to coupon changes ......................................... X
Table 22: Rbs financial institutions ....................................................................... XI
Table 23: Rbs corporations ............................................................................... XI
Table 24: Rating adjustment for the “business position” ..................................... XII
Table 25: Rating adjustments for the “risk position” ............................................... XII
Table 26: Rating adjustments for “liquidity & funding” ........................................ XIII
Table 27: 18-state Rating Transition Matrix (AAA – BBB+) ........................................ XIV
Table 28: 18-state Rating Transition Matrix (BBB+ – D) ........................................ XIV
List of Figures

Figure 1: Regulatory minimal capital requirements ......................................................... 7
Figure 2: Capital ratio-based trigger ............................................................................. 11
Figure 3: Influencing factors of a coco bond’s value ......................................................... 32
Figure 4: Simplified eight-state multinomial model .......................................................... 33
Figure 5: One year, two states financial bond price scenario ........................................... 35
Figure 6: Exemplary 3 year, 8-state multinomial tree ...................................................... 36
Figure 7: Calculating backwards for state T-1 ................................................................. 39
Figure 8: Calculating backwards for state T-2 ................................................................. 42
Figure 9: Changes of rbs across different maturities and ratings .................................... 44
Figure 10: S&P’s Banking rating framework ................................................................. 47
Figure 11: Exemplary construction of the conversion concept ...................................... 48
Figure 12: Conversion value tree .................................................................................. 50
Figure 13: Exemplary coco bond with a call option ....................................................... 52
Figure 14: CSGN.VX price chart .................................................................................. 54
Figure 15: Market spreads vs. Rock-bottom spreads ..................................................... 58
Figure 16: Rbs sensitivity with respect to interest rate changes ..................................... X
Figure 17: Rbs sensitivity with respect to coupon changes ............................................ XI
Figure 18: Financial vs. Corporate rbs ........................................................................... XII
1 Introduction

1.1 Motivation

The 2007-2009 financial crisis highlighted that financial institutions presumably play the most important role in today’s economy. By controlling the world’s liquidity and debt markets, banks can influence the amount of money and the overall investment activities in the market. As soon as the banking industry’s activities deteriorate, large parts of the economy follow suit. In the past, this strong dependency on the financial sector has forced governments all over the world to step in and rescue distressed banks in order to prevent greater damage. These implicit government guarantees have lead to moral hazard accompanied by reckless investment decisions and poor capital management. Even though the regulators apprehended the banks’ behaviour, they were convinced that the financial institutions’ capital reserves as well as the additional T1 and T2 hybrid instruments would provide enough buffer for a possible downturn. Yet, during the crisis, many banks hesitated to avail themselves of their hybrid instruments by calling or converting them into equity. The main problem was that many financial institutions were reluctant to convert their hybrids because they feared negative signalling effects in the market. In addition, an increase in capital was not up for discussion since the low share prices at the time would have led to high dilution among the initial shareholders, thereby agitating the existing owners. In retrospect, many experts criticized that bondholders have been spared any losses, which where then borne by the taxpayers. The ultimate result was a new regulatory framework from the Basel Committee on Banking Supervision. Basel III brought contingent capital into being by restricting all non-contingent hybrid instruments from being allowable against equity capital. The Swiss regulators went one step further by requiring SIFIs to hold a total of 9% of RWA in contingent capital. Ever since, an increasing number of financial institutions have commenced to issue cocos and write-off bonds. So far, these instruments have largely offered “equity-like” returns of 8-10% thereby attracting a large investor base. However, a survey of 150 investors by Nomura displayed that investors valued the bonds by comparing them to similar instruments in the market rather than by applying an independent valuation framework. The academic literature does also not provide a satisfactory answer, since most of the models developed so far are

---

4 Rozanski, 2011.
5 Johnson, 2011.
6 Hughes, 2011, ¶ 4.
based on stock price triggers, whilst the contingent bonds that have been issued all predicate on a capital ratio trigger. Therefore, the objective of this paper is to derive as well as apply a valuation model for contingent capital bonds based on a capital ratio trigger. This will be achieved by extending a hybrid bond model in order to accurately represent the particular characteristics of contingent capital. The valuation process will finally be rounded off with the application of the valuation framework to two recent contingent capital issuances, namely Credit Suisse’s Buffer Capital Note and UBS’s T2 Subordinated Note.

1.2 Thesis structure

The paper consists mainly of four parts. The first chapter will provide a short definition of contingent convertible bonds as well as a distinction between cocos and similar financial asset classes, such as contingent capital and convertible bonds. It will then conclude with a brief survey of the current regulatory environment on the Swiss as well as on the international level.

The second chapter will introduce and evaluate the different trigger and conversion ratio possibilities for the design of a contingent convertible bond. Bank-specific as well as systemic triggers and fixed number as well as fixed value conversion will be the principal constituents of this disquisition.

The penultimate Chapter will introduce the basic rock-bottom valuation model. This model will then be extended and adjusted in order to correctly reflect the special features of contingent capital. All calculations are predicated on the replicated model (Excel VBA based), which can be found on the attached CD at the end of this paper.

The last chapter will highlight how real world bonds can be evaluated with the model. Two recent contingent capital issuances will be used to exemplify the application of the model. Concluding, the derived numbers will be compared to the respective market values in order to assess the results of the model.
2 Contingent Convertible Bonds

2.1 Definition

Contingent convertible bonds also known as coco bonds, enhanced capital notes or contingent capital are a relatively new form of bank hybrid capital.\(^7\) Hybrid bonds – to which coco bonds belong – rank between debt and equity in a bank’s capital structure, since they combine characteristics from both.\(^8\) However, the remarkable trait of coco bonds is that even though they pay a regular coupon (like plain vanilla bonds) there is always the risk of a conversion into equity when the bank experiences a situation of financial distress. This conversion is assured through – previously specified – critical thresholds, which – once undercut – will force the conversion of coco bond capital into equity capital.\(^9\) This trigger could for example be the Core Tier I capital ratio (one of the key regulatory measures for a bank’s health) falling below 5%. Once this level is breached, coco bonds would then automatically be transformed into shares, thereby immediately providing fresh capital to the bank, driving the Core Tier I capital ratio up and decreasing interest expenses.\(^10\) This mechanism enables banks with financial difficulties to automatically increase equity ratios, thereby regaining investors’ trust.\(^11\) If the trigger is not undercut, the coco bond will – like any traditional bond – be paid back at maturity.\(^12\) Contingent convertible capital thereby supports the banks’ capital structure in times of financial downturn without the constraint of tax-inefficient capital in times of financial upturn.\(^13\) Even thought cocos cannot completely replace state guarantees in systemic crises, they do represent a private bailout buffer for individual bank distress. However, as cocos belong to the funded notes, they do not generate new cash at the time of conversion but rather change the liability structure of the respective bank. Therefore, Contingent Convertible bonds are of no help in the event of a liquidity crisis.\(^14\)

---

\(^7\) Koziol & Lawrenz, 2012, p. 90.
\(^8\) Hughes, 2009, ¶ 5.
\(^11\) CoCos, n. d.
\(^12\) Pennacchi, 2010, p.2.
\(^13\) Flannery, 2009, p. 3.
2.2 Categorization of Contingent Convertible Capital

The capital management of today’s banks is currently in the process of adaptation: Many regulation standards as well as requirements for the capital bases of financial institutions have changed dramatically over the last years. The issue of bonds that are able to cover part of the losses will become more and more essential for sustainable capital management. A great variety of convertible as well as contingent capital has been invented over the last years, despite the fact that regulatory accountability has so far not been specified for all financial instruments.  

Nowadays, there are a lot of different financial instruments that belong to the convertible capital class. Table 1 lists the main types of convertible capital as well as their characteristics.

<table>
<thead>
<tr>
<th>Name</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional convertible Bond</td>
<td>A fixed-income security, which gives the issuer the right to convert the bond into a previously specified amount of shares within a certain time period.</td>
</tr>
<tr>
<td>Exchangeable Note</td>
<td>A bond that gives its holder the right to convert it into a previously specified amount of shares. However, unlike a traditional convertible bond, the issuer of an exchangeable is not the company that issues the underlying shares, but typically one of the major shareholders.</td>
</tr>
<tr>
<td>Mandatory convertible Bond</td>
<td>A variation of the traditional convertible bond, which limits the rights of the investors. Whilst the holder of a traditional convertible bond has the right to choose whether he wants to convert his bond or not, the mandatory convertible investor has to convert his bond at maturity at the latest. The risk of losing return in the event of falling share prices is therefore much higher when investing in mandatory convertibles. Due to the fact that the conversion is realised through the issue of new shares, mandatory convertibles are nothing else than an indirect capital increase in combination with an equity dilution for the original shareholders.</td>
</tr>
</tbody>
</table>

15 Zähres, 2011a, p. 3.
16 Zähres, p. 4.
Besides common claims (right of interest and pay back) bonds with warrants also securitize an option on new stock. As for the issuance of mandatory convertible and (un)conditional convertible bonds, bonds with warrants require an indirect capital increase. Contrary to the traditional convertible bond, the conversion option of a bond with warrants can be traded separately.

A convertible bond which converts into a previously specified amount of shares when an afore-determined trigger is surpassed within the duration of the bond.

**Table 1: Different forms of convertible capital**

The main difference between coco bonds and other forms of convertible bonds is that their conversion depends on certain external conditions, such as the share price or the Tier I capital ratio. This dependency on an external trigger event is a well-known characteristic of contingent capital. The terms "cocos" and "contingent capital" are often used interchangeably, but the generic view is that contingent capital contains a great variety of financial instruments, to which contingent convertible bonds belong. Contingent capital can generally be divided into two categories, which differ concerning the trigger consequences to the effect that the principal amount is either turned into equity or written off (see table 2).

<table>
<thead>
<tr>
<th>Description</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coco</td>
<td>Long-term subordinated debt with fixed coupon payments</td>
<td>Banks are incentivized to reduce risk and to improve capital management</td>
</tr>
</tbody>
</table>

17 On the basis of Zähres, 2011a, p. 6 / for a more detailed overview see also Noddings, Christoph & Noddings, 2001.

Contingent Convertible Bonds

| Write-off Bond | Write off instead of conversion | Larger investor base, since investors that are restricted from holding equity can invest in these instruments. | Danger of an inverted capital structure: bondholders could bear losses prior to shareholders. |
| Temporary Write-off Bond | Write off is only temporary | Lower issuing costs, since investors would prefer this bond structure. | Is not considered allowable against equity requirements |

Table 2: Different forms of contingent capital

Any financial instrument that turns into equity or will be reduced in par value after a trigger event occurred generally belongs to the class of contingent capital. However, a coco bond will – per definition – always convert into equity after the trigger event occurred and is therefore one particular form of contingent capital.

2.3 The Regulatory angle

The financial crisis of 2007-2009 underlined the various mistakes within the capital framework of financial institutions. Until then, regulatory capital consisted mainly of two parts, namely the so-called Tier 1 and Tier 2 capital. Tier 1 or going-concern capital had the objective to absorb bank losses while the financial institution was still solvent. Tier 2 or gone-capital, by contrast, only covered losses after the bank had already entered default. During the financial crisis, banks had alarmingly low capital buffers, since Tier 2 capital was completely useless in the going-concern context and banks were reluctant to call or defer their bonds due to negative signalling effects. In fact, only a small part of the Tier 1 capital

---

Contingent Convertible Bonds

(namely core capital) was effectively loss absorbing.\textsuperscript{20} In addition, many companies were disinclined to issue new capital. The extremely low share prices would have caused high dilutions among the existing shareholders, which bank managers tried to avert as long as possible.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{Regulatory minimal capital requirements\textsuperscript{21}}
\end{figure}

On January 13, 2011 the Basel Committee on Banking Supervision finally altered the bank capital requirements in order to address the discovered shortcomings.\textsuperscript{22} Figure 1 summarizes the new Basel III and Swiss Finish minimal capital requirements and compares them to the old Basel II regulatory framework. The Basel Committee on Banking Supervision decided that under Basel III all non-common T1 and T2 instruments must appertain to the contingent capital class.\textsuperscript{23} The Swiss government imposed even stricter regulations by requiring Swiss SiFIs to hold a total of 10\% (of RWA) as common equity and an additional 9\% (of RWA) in contingent capital.\textsuperscript{24} These new requirements on the Swiss as well as on the global level, will lead to a raise in contingent capital issuances over the next years accompanied by an increase in the importance of qualified coco designs.

\textsuperscript{20} Maes & Schoutens, 2010, p. 2.
\textsuperscript{22} Bank für internationalen Zahlungsausgleich, 2011, p. 1.
\textsuperscript{24} Die neue „too big to fail“-Regulierung ist unter Dach, 2011 / Abegglen et al., 2011.
3 Elements of Contingent Convertible Bonds

In order for a coco structure to be successfully established in the market, there are mainly three interest groups one has to bear in mind. Firstly, the regulators, who need to be convinced that the coco bond has absolute lost bearing abilities in the recovery phase.\textsuperscript{25} Secondly, the shareholders, whose shares become diluted through the automatic equity capital increase and who therefore prefer no dilution effect at all or at least only a marginal one. Finally, there are the investors, uncertain as to what they should expect and whether they will even be permitted to hold these instruments.\textsuperscript{26}

In addition, it is important to realize that the contingent convertible bonds’ conversion terms do not only impact the risk bearing, but also influence the incentives to take risk.\textsuperscript{27} The design of the bond’s terms and conditions is therefore essential and at the same time quite difficult.\textsuperscript{28}

When designing a contingent convertible bond, there are mainly two aspects that need to be determine, namely the conversion trigger (the specified event[s] that cause[s] conversion) and the conversion ratio (meaning the amount of shares into which the bonds will be converted).\textsuperscript{29} Consequently, the following paragraphs will analyze the different trigger as well as conversion ratio options that exist when creating a coco bond.

3.1 The Trigger

The trigger of a contingent convertible bond is the threshold that determines the probability and therefore the risk of conversion.\textsuperscript{30} In order to provide the promised recovery to the issuing financial institution, a good trigger must fulfil a variety of requirements. Among others, it is essential that the conversion is executed early enough to help the respective financial institution\textsuperscript{31}, whilst only taking place if the financial institution is really in need. There have been ongoing discussions in the last years concerning the type and size of the trigger. On the one hand, there are the proponents of bank specific triggers, such as a specific T1 capital ratio,

\begin{thebibliography}{9}
\bibitem{25} Pazarbasioglu et al., 2011, p. 4-5.
\bibitem{26} Mathers, 2011, slide 6 / Zähres, 2011a, p. 5-6.
\bibitem{27} Flannery & Perotti, 2011, p. 1.
\bibitem{28} Zähres, p. 5-6.
\bibitem{29} Calomiris & Herring, 2011, p. 2.
\bibitem{30} Pazarbasioglu et al., p. 8.
\bibitem{31} Maes & Schoutens, 2010, p. 10.
\end{thebibliography}
CDS spread or the issuer’s share price, whilst others favour a more systemic trigger, such as an index or an intervention by regulators evoked by the existence of a financial crisis. Many authors also present arguments for a dual-price trigger, which incorporates a bank-specific as well as a systematic trigger.

Due to this diversity in trigger structures, the following paragraphs explain the respective reasons behind the different designs as well as the pros and cons of the different forms in detail.

### 3.1.1 Bank-specific trigger

Bank-specific triggers are based solely on the economic state of a single financial institution. Even though these triggers might not be enough to save the entire system in a system-wide financial crisis, they still help each distinct financial institution in times of individual, independent financial distress. Furthermore, the focus on the single financial institution has a positive ex ante risk mitigating effect by creating strong incentives for shareholders as well as managers to control their risks.

Some examples of bank-specific triggers are the core T1 capital ratio, CDS spreads, the issuer’s share price or the assessment of non-viability by the supervisors. The first three examples are at an advantage concerning the objectiveness of the trigger event, since regulator’s discretion is often regarded with suspicion. Among those three, the capital ratio trigger is probably the one best in line with the regulatory capital framework and its objectives. But since it is often a lagging indicator of the current state of the financial institution, it may not trigger a conversion early enough. Market-based triggers, on the other hand, are indeed more suitable to indicate the financial condition of the issuer, but can be manipulated much more easily, thereby raising the risk of untimely conversion.

It is therefore essential to take the different interests – of shareholders, bondholders, regulators and investors – as well as the pros and cons of the different bank-specific triggers into consideration when designing a contingent convertible bond. Table 3 provides a short overview of the main advantages and disadvantages of the different bank-specific triggers, of which the capital ratio trigger as well as the market-based trigger will be expatiated on in the following sections.

---

32 Pazarbasioglu et al., 2011, p. 9.
<table>
<thead>
<tr>
<th>Trigger type</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital ratio-based trigger</td>
<td>Easier to price</td>
<td>Low publication frequency (quarterly) =&gt; high probability of lags in the appraisal of the financial condition</td>
<td>Conversion if the T1 capital ratio (Core T1 to RWS) falls below 5% (Lloyds)</td>
</tr>
<tr>
<td></td>
<td>Straight forward understanding and implementation</td>
<td>Exact trigger level at which financial distress begins is hard to determine ex ante</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Disclosed</td>
<td>Backward looking</td>
<td></td>
</tr>
<tr>
<td>Market-based trigger</td>
<td>Forward-looking (implying an efficient market)</td>
<td>Market can be distorted or manipulated (especially in times of economic distress)</td>
<td>Conversion if the stock price falls below a predetermined level</td>
</tr>
<tr>
<td>(E.g. share price, CDS spreads)</td>
<td>More information at an earlier state (do not have to wait for quarterly financial statements)</td>
<td>Higher probability of premature conversion</td>
<td>Conversion if the CDS exceeds a previously specified level</td>
</tr>
<tr>
<td>Regulators’ discretion to trigger conversion</td>
<td>Addresses the timeliness problem of capital ratios</td>
<td>No automatic conversion =&gt; negative signalling problem</td>
<td>Conversion if financial institution fails a stress test (for instance the Fed’s stress tests)</td>
</tr>
<tr>
<td></td>
<td>Uncertainty of the outcome reduces market manipulation</td>
<td>Negative signalling effect may cause regulators to delay conversion for too long</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>More expensive: investors may require a premium for the uncertainty pertaining to the outcome of the stress test</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Characteristics of bank-specific triggers

---

33 On the basis of Pazarbasioglu et al., 2011, p. 24-25.
### 3.1.1.1 Capital ratio-based trigger

A capital ratio-based trigger converts bond capital into equity if and when the Tier I capital ratio falls below a certain value, which has either been determined by regulators or by a previously signed contract.\(^{35}\) If a bank – devoid of coco capital with a capital ratio trigger – experiences financial distress, capital ratios begin to decline and negative signals are displayed in the market. Investors as well as clients become alarmed and lose trust in the bank. This lack of confidence causes further losses for the financial institution – as has been seen in the recent financial crisis – as well as a further decline in equity capital and ultimately leads to either a government bailout or insolvency. As displayed in figure 2, a capital ratio-based trigger can help prevent this deadly spiral by providing additional equity capital to the distressed financial institution. In doing so, it restores investors’ trust, prevents bankruptcy and gives the respective financial institution a chance to recover.

In light of its transparency and objectiveness, the capital ratio-based trigger is also an interesting design for other stakeholders. Investors, for example, can easily assess and model coco bonds with such a capital ratio threshold. Furthermore, holders of coco bonds with a capital ratio-based trigger would not have to bear the dependency on regulators’ distinction or the volatility of easily manipulated markets which the other trigger options imply.\(^ {36}\)

However, the capital ratio trigger has also met a lot of criticism. Opponents primarily challenge the trigger’s high dependency on accurate accounting. As the accounting process takes up quite a bit of time, accounting statements are generally published only four times a year.\(^ {37}\) Many investors fear that the true state of the financial institution will not be revealed until the damage is too large to avert.\(^ {38}\) Besides the time aspect, many detractors of capital ratio triggers also criticise the large flexibility of accounting rules such as US GAAP. These

---

\(^{34}\) On the basis of Maes & Schoutens, 2010, p. 11.

\(^{35}\) Pitt et al., 2011, p. 6.

\(^{36}\) Pitt et al., p. 6-7.


\(^{38}\) McDonald, 2009, p. 22.
accounting regulations provide managers with a great assortment of rules and tools which give them lots of freedom regarding the exact time and amount of value adjustments. Especially in situations of financial distress, book equity value often lags in disclosing changes in market value.\textsuperscript{39} This effect has been witnessed recently during the financial crisis 2007, where many of the most troubled firms were still qualified as being well capitalized according to the Basel II framework.\textsuperscript{40} Apart from management influence there are also the politicians, who have quite some impact when it comes to accounting rules. Since there have been some political interventions in the process of accounting rule creation in the 2007-2009 financial crisis, it can be assumed that for future crises accounting regulations could be manipulated as well. One can therefore conclude that the capital ratio-based trigger only were ideal in a world in which financial institutions are aboveboard, auditors competent and regulators thoughtful.\textsuperscript{41}

Even after discussing the pros and cons of coco capital with a capital ratio-based trigger, the question persists as to whether contingent capital converts early enough to help the issuing institution.\textsuperscript{42} Of course, the frequency with which the trigger is monitored is important (as has been argued above), but the absolute trigger level also plays a vital role when it comes to the exact time of conversion.

### 3.1.1.2 High- versus low-trigger Cocos

The absolute trigger level is the measuring value of conversion risk. It stands to reason that a high-trigger coco bond is much more likely to be converted than a low-trigger coco bond. This difference in conversion risk as well as loss sharing attracts different types of investors. Conservative, long term, fixed-income investors are more attracted to low-trigger cocos which are rather unlikely to convert, whilst speculative, high-yield investors would most likely prefer the high-trigger coco with a higher probability of conversion and loss, but also higher returns.\textsuperscript{43} However, if low-trigger coco bonds have high-trigger cocos ahead of them, they will be less likely to convert, since the high-trigger cocos will be converted long before the lower capital ratio levels are reached. It is therefore almost impossible to detect which type of capital ratio trigger is the riskier one, unless one knows the exact composition of the entire contingent capital. In order to circumvent investors’ uncertainty, financial institutions should

\textsuperscript{39} Flannery, 2009, p. 2.
\textsuperscript{40} Kuritzkes & Scott, 2009, ¶ 4.
\textsuperscript{41} McDonald, 2009, p. 23.
\textsuperscript{42} Maes & Schoutens, 2010, p. 10.
\textsuperscript{43} Pazarbasioglu et al., 2011, p. 12.
either initiate their issuing activities with high-trigger cocos or at least announce the exact target trigger mix.\textsuperscript{44}

From a regulatory viewpoint, the distinct trigger levels do not only represent diverse conversion risks, but also pursue different objectives (as displayed in table 4).

<table>
<thead>
<tr>
<th>Debt Instruments</th>
<th>Trigger</th>
<th>Financial condition</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High-trigger Coco</strong></td>
<td>Example: T1 Capital ratio of 7% (common equity to risk weighted assets)</td>
<td>Deteriorating financial condition (going concern)</td>
<td>Recapitalization in order to stabilize the situation and to regain investors’ trust</td>
</tr>
<tr>
<td><strong>Low-trigger Coco</strong></td>
<td>Examples: T1 Capital ratio of 5% (common equity to risk weighted assets) Point of non-viability or other resolution triggers</td>
<td>Threat of collapse (going concern) Threat of insolvency (going/gone concern)</td>
<td>Provision of additional recapitalization to prevent bankruptcy Compulsory restructuring in order to prevent insolvency</td>
</tr>
</tbody>
</table>

*Table 4: Low vs. high trigger contingent capital*\textsuperscript{45}

Low-trigger cocos give banks the potential to delay necessary recapitalizations for a longer period of time. Whilst capital ratios decline and shareholders have diminishing value at risk, it becomes increasingly rational for banks to take higher risks. In addition, receding capital ratios cause negative signals in the markets thereby leading to dwindling depositors’ confidence and hence an increased likelihood of bank runs and ultimately government interventions or bankruptcy. That is to say, if cocos will only convert at the point of bank failure, banks will continue to operate under high leverage, where the potential of shifting risks from shareholders to lenders and taxpayers will boost their risk-taking incentives even more – just as was the case in the years prior to 2008. High-trigger cocos and a therewith-accompanied early conversion, on the other hand, could act as a risk prevention tool by shifting the control

\textsuperscript{44} Von Furstenberg, 2011, p. 10.

\textsuperscript{45} On the basis of Pazarbasioglu et al., 2011, p. 10.
of the financial institution from shareholders to investors at an earlier stage. Such an early conversion has two negative impacts on the initial shareholders.\textsuperscript{46} Firstly, the initial shareholders might lose control over the company (highly depending on share price and conversion terms) and secondly, due to decreased leverage and the increased number of outstanding shares, the dilution in share prices causes a decline in earnings for the initial shareholders.

Finally, there is the risk of a conversion panic, which needs to be taken into consideration when balancing high and low-trigger cocos. Even though a conversion indeed restores solvency and trust in the converting bank, it might also cause a damming light on the financial condition of the converting institution. This could lead to an investor panic accompanied by declining confidence in the remaining financial system, which would ultimately result in a flood of conversions. A high trigger could prevent this outcome by ensuring that conversion takes place at a considerably high equity value and in an environment where the remaining financial institutions are still rather soundly financed.\textsuperscript{47} High-trigger cocos can hence initiate a bank’s recapitalization well before it faces serious financial distress, thereby disrupting the downward spiral and stabilizing the financial condition of the bank.\textsuperscript{48}

Instruments with low-level triggers, on the other hand, are much more suited for controlled resolutions. By setting the trigger at the point of non-viability, financial regulators can assure that the private sector will be involved in the restructuring process of the respective bank, which is expected to minimize costs for taxpayers. However, these low-level triggers could have the contrary effect by reducing rather than enhancing market confidence as the capital ratio approaches the trigger level. This underlines the importance of a careful implementation of these triggers – maybe even accompanied by some additional liquidity reserves and government interventions – in order to achieve an increase, rather than a decrease, in the bank’s chance of survival.\textsuperscript{49}

The Swiss Financial Market Supervisory Authority FINMA was the first to come up with a contingent capital proposal. The Too-Big-To-Fail Commission of Experts has recommended a contingent capital construct, which mainly consists of two instruments with different issue sizes and trigger-levels. The first tranche amounts to 3% of RWA and consists of contingent capital with a Tier I capital ratio-based trigger of 7%. The second tranche has a trigger of 5 %

\textsuperscript{46} Flannery & Perotti, 2011, p. 2.
\textsuperscript{47} Flannery & Perotti, p. 6.
\textsuperscript{48} Pazarbasioglu et al., 2011, p. 9.
\textsuperscript{49} Pazarbasioglu et al., p. 10.
and adds up to 6% of RWA.\(^{50}\) It is quite reasonable to have a larger share in low-trigger coco capital since, in the event of low-trigger conversion, the financial institution’s Tier I capital ratio will be much lower than it would be in the event of a high-trigger conversion. Due to the bad financial state of the bank and the smaller capital cushion, the financial institution would need much more equity to sufficiently restore capitalization to the going-concern level.\(^{51}\) In this situation, a stabilization of the financial institution can only be ensured if enough capital is provided to regain market confidence.

Even though there have been many discussions concerning the pros and cons of high- and low-trigger cocos, it has not yet been defined where the high-trigger ratio ends and the low-trigger ratio begins. The higher trigger, for example, has to be set – per definition – at a sufficiently high level, where it can ensure conversion at a time when the financial institution is still fully viable. On the other hand, it should not be so high as to be triggered in the event of a mild downturn. The same is true for the lower trigger, which cannot permit losses to accumulate for too long, as this would lead to inevitable damage. The Swiss authorities, as well as the Basel Committee, have decided in favour of a dual-level capital ratio trigger. Yet, the markets must be given some time before a reasonable assessment can be reached.

### 3.1.1.3 Market-based trigger

The market-based trigger coco bond converts into equity if and when the issuer’s share price or CDS spread breaches a certain level. The obvious advantage is the dependency on market sentiment rather than on managers’ honesty or regulators’ thoughtfulness. Market values are considered to be rather forward-looking and substantially quicker to display changes in the issuer’s financial condition. As already briefly addressed in the previous chapter, many of the failing banks in 2008 had, according to Basel II standards, presumably been better capitalized than those that did not collapse.\(^{52}\) This casts doubt on the suitability of capital ratio triggers for the assessment of a bank’s financial situation and hence strengthens the case of cocos with a market-based trigger.

Market prices reflect the financial condition of their issuer on an ongoing basis. While financial statements are in most cases only disclosed on a quarterly basis, share prices or CDS spreads can be requested almost continuously (by making use of all stock exchanges around the world).

---

\(^{50}\) Von Furstenberg, 2011, p. 10.

\(^{51}\) Pitt et al., 2011, p. 2 / Von Furstenberg, p. 10.

\(^{52}\) Kuritzkes & Scott, 2009, ¶ 4.
Furthermore, market prices often incorporate off-book information which normal accounting equity measures might ignore.\(^{53}\) They are therefore often assumed to be considerably more accurate in representing the true equity value of a firm than book equity, which, especially in the event of a financial crisis, is often overstated and purposely manipulated.\(^{54}\)

Given the above, it may seem reasonable to design cocos with a plain market-based trigger. However, there are also some negative market characteristics that need to be considered. One important disadvantage of market-based triggers is their vulnerability to market manipulation. The holder of a coco bond with a market price trigger might be tempted to short sell the respective share in order to push the price below the trigger level. After conversion, the prices return to their “correct” levels – above the trigger price – and the short seller would realize a profit.\(^{55}\) In some situations, short sellers might be able to raid the market to the point where the share is on the brink of worthlessness, which would then provoke a destabilization of the entire financial institution.\(^{56}\) Admittedly, such negative manipulation effects can easily be mitigated by basing the trigger on average rather than daily share prices. If conversion were based on the average closing share price of say the last 20 trading days, the short seller would have to keep the price down for a considerably longer period.\(^{57}\) The arbitrageur would further need to invest considerably larger amounts of money in order to manipulate the stock price for such a long time, which makes the manipulation both more improbable and easier to discover.\(^{58}\) Besides the trigger value, there is also the conversion ratio, which can help to protect cocos from speculative attacks. If the conversion ratio has been designed anti-dilutive, meaning that the value of the exchanged shares is smaller than the par value of the bond, speculative investors would not profit from a short price fall since the loss at conversion would be higher than the possible benefits.\(^{59}\)

The fear of a self-reinforcing downward movement of stock prices as these approach the trigger level is widely spread and often referred to as “death spiral”. It could be argued that this discontinuity in share price behaviour embodies a distortion created by market-based triggers. However, since a coco conversion (at par value) is accompanied by a dilution of current equity, it is absolutely reasonable for markets to anticipate this loss. This anticipation

\(^{53}\) Flannery, 2009, p. 10.
\(^{54}\) Flannery, p. 16.
\(^{55}\) Pennacchi et al., 2011, p. 5. / McDonald, 2009, p. 11.
\(^{56}\) Flannery, p. 18-19.
\(^{58}\) McDonald, p. 11.
will be incorporated in market prices, thereby leading to an even faster decline.\textsuperscript{60} Death spirals can therefore force conversions in situations, where they might not be justified by the underlying financials.\textsuperscript{61}

Another objection to market-based triggers is their often-questioned ability to signal financial risk. Equity is the most risky financial instrument in the capital structure and therefore also the most likely to be misvalued.\textsuperscript{62} Price volatility, investor panics or other market pricing errors might lead to a situation where cocos are unnecessarily converted. These market errors are usually considered to be random and the distortions caused by random pricing errors would still be preferable to those founded in wrong accounting.\textsuperscript{63} Yet, in a major financial crisis, market-pricing errors cease to be random and become positively correlated across firms and time. In a systemic crisis, cocos with market-based triggers would be converted in large numbers thereby releasing – within a short period of time – a large amount of new equity into the market.\textsuperscript{64}

Moreover, in a financial crisis, the market price and with it the equity value of the firm would become highly volatile and merely aligned with the underlying fundamentals. Negative business outlooks would further increase volatility by adding noise to share price movements. Stock prices would thus lose their ability to accurately depict the financial condition of a firm at a time when their capabilities are absolutely essential.\textsuperscript{65}

In conclusion, it must be said that the “right trigger” is highly dependent on the respective interest group. Many investors prefer market triggers because they are much easier to price and disburden risk management through the facilitation of hedging possibilities.\textsuperscript{66} Issuers on the other hand generally favour a discretionary trigger since it provides them with a buffer during which regulators may wait and hope for an improvement in the financial condition of the issuer.\textsuperscript{67} Regulators have a rather critical view of market-based triggers, due to their scepticism concerning the market's ability to accurately display financial risk and the share prices' high - and sometimes irrational - volatility. Accounting triggers, in contrast, are less volatile and therefore preferred by regulators. However, with the implementation of Basel III, incentives will change (as has been addressed in Chapter 3.1.1.2.) thereby potentially im-

\begin{itemize}
\item \textsuperscript{60} Flannery & Perotti, 2011, p. 5.
\item \textsuperscript{61} Pitt et al., 2011, p. 8.
\item \textsuperscript{62} Pennachi et al., 2011, p. 3.
\item \textsuperscript{63} Flannery, 2009, p. 16-17.
\item \textsuperscript{64} Von Furstenberg, 2011, p. 17.
\item \textsuperscript{65} Von Furstenberg, p. 19.
\item \textsuperscript{66} Flannery & Perotti, p. 5.
\item \textsuperscript{67} Pitt et al., p. 12.
\end{itemize}
proving stock prices’ qualification to adequately measure financial risk.\textsuperscript{68} This in turn could lead to a modification in the regulatory trigger construction.

### 3.1.2 Systemic trigger

Systemic triggers, contrary to bank-specific triggers, do not pursue the goal of helping an individual financial institution, but rather have the objective to increase capitalization across the entire financial industry in the event of a systemic crisis. They are either based on regulators’ judgment or sector-wide crisis indicators, such as loss rates, sector indices and market capitalizations.\textsuperscript{69} Table 5 summarizes the main advantages and disadvantages of the two different trigger types.

<table>
<thead>
<tr>
<th>Trigger type</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General condition of the financial sector</strong></td>
<td>Increases the financial sector's capitalization in the event of a systemic crisis</td>
<td>Lack of differentiation among financial institutions might have undesirable consequences</td>
<td></td>
</tr>
<tr>
<td>(Loss rates, indices and capitalization)</td>
<td>Automatic conversion and hence no reliance on regulators’ discretion</td>
<td>Absence of potential regulatory intervention may cause difficulties in crises with little or no precedent</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Trigger definition might be too narrow: e.g. if conversion is triggered by a certain capitalization level and a crisis emerges which does not impact that value.</td>
<td></td>
</tr>
<tr>
<td><strong>Regulatory declaration of a systemic crisis</strong></td>
<td>Broad recapitalization of the entire financial industry if and when regulators consider it to be necessary</td>
<td>Lack of differentiation among the financial institutions might have undesirable consequences and leads to inefficient recapitalization</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Strong dependency on regulators’ judgement might be counterproductive</td>
<td>The European Committee of the European Central Bank declares a systemic crisis\textsuperscript{70}</td>
</tr>
</tbody>
</table>

\textsuperscript{68} Flannery & Perotti, 2011, p. 5-6.

\textsuperscript{69} Pazarbasioglu et al., 2011, p. 25-26.

\textsuperscript{70} Maes & Schoutens, 2010, p. 12.
Elements of Contingent Convertible Bonds

<table>
<thead>
<tr>
<th>Elements</th>
<th>Contingent Convertible Bonds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Characteristics of systemic triggers\textsuperscript{71}

Even though systemic triggers have the advantage of efficiently providing large amounts of equity in the event of a systemic crisis, they also annihilate the positive incentives offered by more individual, bank-specific triggers. If contingent convertible capital is only triggered in the event of a financial crisis, banks no longer have an impact on their own future and therefore no reason to manage their individual risks in an efficient way. Systemic discretionary triggers are therefore much more suited for the state of non-viability rather than for going-concern contingent capital. In a situation where equity ratios approach the lower trigger level, risk prevention incentives have obviously malfunctioned. Banks have failed to rescue themselves and regulators’ judgement henceforth resumes control over the late conversion stage.\textsuperscript{72}

But even in a late conversion state, there remains the problem of the first troubled bank. The first distressed financial institution cannot access its contingent capital reserves until the supervisors have declared a systemic crisis. This would most likely lead to a situation where the first troubled bank would not be able to recapitalize before it is too late. Consequently, regulators would have an incentive to declare systemic crises too frequently.\textsuperscript{73}

On the other hand, given the uncertainty when it comes to asset valuation and shareholders’ aversion to conversion, a trigger based solely on regulatory discretion is rather likely to delay recapitalization. When additionally taking the long history of supervisory forbearance in banking into consideration, excess and delayed recapitalization becomes a certainty.\textsuperscript{74} Regulators face a predicament when it comes to declaring systemic crises since it is always question-

\textsuperscript{71} On the basis of Pazarbasioglu et al., 2011, p. 25-26.
\textsuperscript{72} Flannery & Perotti, 2011, p. 6.
\textsuperscript{73} Maes & Schoutens, 2010, p. 12.
able whether the positive consequences, namely multiple recapitalizations will outweigh the potential negative impacts, such as negative signalling in the market and severe loss of confidence. They are therefore enticed to delay conversion for as long as possible in the hope of an improvement in the financial sector.\textsuperscript{75} This inactiveness could, however, protract recapitalization, until it might be too late, thereby ultimately leading to increased government resolution costs.\textsuperscript{76}

Moreover, due to the complexity of predicting a systemic crisis and the aspect of randomness in regulators' judgement, pricing of such coco instruments would be quite difficult and – as a result of increased uncertainty – rather expensive.\textsuperscript{77} Furthermore, a discretionary trigger makes coco instrument highly difficult to model, which could in turn cause fund mandates to prohibit their fund managers – which are the largest group of potential coco investors – to buy these instruments.\textsuperscript{78}

These negative implications of regulators' discretion militate in favour of a market based systemic trigger, such as an index. In comparison with bank-specific market-based triggers, an index would be much less susceptible to manipulation. It would presumably be impossible for a short seller to influence an entire index for even a few days, not to mention a longer period of time.\textsuperscript{79} Furthermore, a market index would – just like market-based triggers – be disclosed continuously and open to the public. Due to the availability of historical data and economic forecasts, stock price indices can be modelled to a certain extent, which would again simplify the valuation process of coco instruments. On the other hand, there is the question of the “correct” market-based systemic trigger. This trigger has to be highly correlated with the status of the entire financial industry. Especially since no two systemic crises are alike with respect to their effects, implications and outcomes, it is presumably impossible to determine a market trigger, which can accurately identify the beginning of a financial crisis. In addition, an inappropriate trigger would put the entire financial system in jeopardy by causing coco capital to trigger either too early or – even worse – not at all.

Many regulators prefer the discretionary trigger since it provides them with large flexibility concerning when, why and how much to convert. The regulating authorities espouse the view

\textsuperscript{74} Flannery & Perotti, p. 6.
\textsuperscript{75} McDonald, 2009, p. 9.
\textsuperscript{76} Flannery, 2009, p. 13.
\textsuperscript{77} Pennacchi et al., 2011, p. 7 / Pazarbasioglu et al, 2011, p. 9.
\textsuperscript{78} Pitt et al., 2011, p. 13.
\textsuperscript{79} McDonald, p. 12-13.
Elements of Contingent Convertible Bonds

that, due to their meta-level insight, they are much more competent to handle the complexity of systemic crises and to assess the overall condition of the financial sector.\textsuperscript{80}

But even if regulators are able to accurately declare a financial crisis, systemic triggers still have the downside of forcing all banks to convert their contingent convertible capital. This conversion is exercised regardless of the banks’ individual financial states, thereby penalizing the well-capitalized, solid financial institutions with additional unnecessary as well as expensive equity capital. Consequently, it would be advisable to implement an additional trigger in order to prevent over-capitalization. The Squam Lake Working Group, for example, recommends a dual trigger, which requires the declaration of a systemic crisis by regulators as well as the violation of stipulated covenants.\textsuperscript{81}

### 3.1.3 Dual Trigger

As highlighted in the previous section, it is sometimes necessary to implement two triggers in order to ensure accurately timed conversions. In the majority of cases, these dual-trigger cocos consist of a bank-specific and a systemic trigger. Table 6 provides a summary of the pros and cons of this prevalent structure.

<table>
<thead>
<tr>
<th>Trigger type</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dual trigger</td>
<td>Broad recapitalization of the financial sector whilst still allowing differentiation among the individual banks.</td>
<td>Susceptible to sending mixed messages: Regulatory judgement vs. market perception of systemic distress.</td>
<td>For financial institution X: Conversion occurs if and when regulators declare a systemic crisis AND X’s Tier I capital ratio falls below 5%</td>
</tr>
</tbody>
</table>

\textit{Table 6: Characteristics of dual-triggers}\textsuperscript{82}

As already briefly addressed in the preceding chapter, The Squam Lake Working Group recommends such a dual-trigger coco structure. They advance the view that coco capital should

\textsuperscript{80} Pitt et al., 2011, p. 8.
\textsuperscript{81} SLWG, 2009, p. 4.
\textsuperscript{82} On the basis of Pazarbasioğlu et al, 2011, p. 26.
convert into equity if the regulating authorities declare a systemic crisis and the bank’s capital ratio simultaneously falls below an afore-stipulated level. The first objective of this structure is to sustain the positive incentives provided by debt capital, whilst providing some help in extreme crises. In their opinion, debt is a highly important incentive for a company to efficiently manage risk. Converting coco capital as soon as a bank faces difficulties removes these positive incentives and encourages careless as well as inefficient capital management. By limiting conversion to the event of a crisis, debt capital can retain its disciplinary force in all but the most extreme cases. The second objective of the Squam Lake Working Group’s dual trigger is to decrease the pressure on regulators’ discretion as well as preventing overcapitalization during a systemic crisis (see chapter 3.1.2). According to the SLWG, a trigger based solely on regulators’ judgement would exert great political pressure on regulators’ decision process. Also, a replacement of regulators’ discretion with objective market-based systemic triggers would not improve the situation, since the required data is considered to be imprecise, dependent on revisions and recorded with time lags.83

Credit Suisse, who issued coco bonds in February 2011 and March 2012, has chosen a slightly different approach: CS’s coco capital trigger predicates on the capital ratio (strictly speaking the T1 capital ratio) and regulators’ discretion. The wide difference between CS’s and the SLWG’s proposal lies in the independency of the two triggers. While the SLWG’s coco capital will only be turned into equity if both triggers are pulled, breaching one trigger is already sufficient for CS’s capital to convert.84 The intention of CS’s two stand-alone triggers is to help the respective bank during both a financial crisis and a period of individual financial distress.

McDonald follows a different approach by constructing a dual-trigger that only factors market prices into the trigger event and is therefore not at all dependent on accounting regulations or regulators’ discretion. His dual-trigger coco automatically converts into equity if the stock price of the respective bank undercuts a certain value and if a certain financial index falls simultaneously below a previously specified level. The objective behind this construct is to only convert coco capital in the event of a sector wide share price decline, which is expected to occur in a system-wide crisis. Hence, McDonald’s dual-trigger is aimed at the recovery of weakly performing financial institutions in a systemic financial crisis, while permitting individual bankruptcies in “normal” times. This is due to the fact that coco capital will not be converted if only the individual share price threshold is triggered. In these cases, the financial

83 SLWG, 2009, p. 4.
institution would default and coco bondholders would be subordinated and receive – as any other subordinated debt holder – the potential recovery value.\(^{85}\)

However, McDonald’s trigger structure seems to be partly redundant. In a financial crisis stock price movements are highly correlated. Stock price indices and the individual banks’ share price would therefore decline alike, turning coco capital with single market-based triggers as well as coco capital with dual-triggers equiprobable into equity, thereby superseding the index-based trigger.\(^{86}\)

Yet, the second triggers’ contemporaneous conversions could worsen the stability of the financial industry.\(^{87}\) Were this index-based trigger finally breached, numerous shares would be released at once into the market, thereby beating down prices and eventually leading to a destabilization of the entire financial system.\(^{88}\)

### 3.2 Conversion terms

The second important design feature of coco capital is the conversion ratio, which defines how many shares each coco bondholder will receive in exchange for his face value. Therewith, the conversion ratio also determines the burden sharing between the initial shareholders and the coco bondholders. Given that the incentives to supervise bank management highly depend on the question of who will lose in the case of conversion, the question of the “right” conversion ratio becomes vital. If cocos have a high rate of dilution among conversion, shareholders will have to carry the main part of the burden and contrariwise if dilution among conversion is low, the bondholders will be at a disadvantage.\(^{89}\)

In the course of several discussions among a multiplicity of experts, two main conversion types have evolved which differ mainly in their exchange rate calculation. A coco bond can basically be either turned into a fixed number of shares or a fixed amount of equity, each option having its pros and cons, as briefly summarized in table 7.

---

\(^{85}\) McDonald, 2009, p. 2, 4 & 6-7.

\(^{86}\) Von Furstenberg, 2011, p. 11.

\(^{87}\) Von Furstenberg, p. 11.

\(^{88}\) Sakoui & Jenkins, 2009, ¶ 8 / Von Furstenberg, p. 11.

\(^{89}\) Pazarbasioglu et al., 2011, p. 11.
<table>
<thead>
<tr>
<th>Conversion type</th>
<th>Description</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fixed value conversion</strong></td>
<td>At conversion, bonds are transformed into a certain amount of equity</td>
<td>Provides valuation certainty for the coco capital investors.</td>
<td>Change of control in the event of conversion is highly likely (disadvantage for shareholders)</td>
<td>Conversion at time t with a current share price $S_t$: Coco bond with face value $F$ turns into $\frac{F}{S_t}$ shares.</td>
</tr>
<tr>
<td><strong>Fixed number conversion</strong></td>
<td>At conversion, bonds are converted into a certain number of shares</td>
<td>Previously specified amount of dilution for shareholders (can eliminate the risk of CoC) Discourages trigger breaches as long as the share price is not sufficiently low and the issuing institution operates close to its default barrier. (Partly demoralizes stock price manipulations)</td>
<td>Causes valuation uncertainty among investors Higher funding costs for the issuing institution</td>
<td>At conversion: A coco bond with face value $F$, issued at time $t=0$, will convert into $\frac{F}{S_0}$ shares.</td>
</tr>
</tbody>
</table>

*Table 7: Characteristics of different conversion options*\(^9^0\)

The subsequent chapters are aimed at providing a more detailed analysis of the different conversion options.

---

\(^9^0\) On the basis of Pazarbasioglu et al., 2011, p. 27-18.
3.2.1 Fixed value conversion

The main characteristic of a fixed value conversion is the fixed ratio between coco capital and received equity capital. This fixed conversion ratio\(^\text{91}\) equals exactly one if the conversion is exercised at par; it is larger than one if conversion is exercised below par and consequently smaller than one if conversion is exercised above par. Furthermore it is often differentiated between market value and par value conversion (see table 8 for details). Yet, what all fixed value conversions have in common is that the exact number of shares will not be known until the trigger level is breached and the bonds are converted. Table 8 provides an overview of the complex impacts that the different conversion forms can have on share- as well as on bondholders.

<table>
<thead>
<tr>
<th>Conversion</th>
<th>Description</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>At par value</strong></td>
<td>Upon conversion, the bondholder receives an amount of equity capital which is equivalent to the bond’s face value</td>
<td>Lower issuing costs for financial institutions</td>
<td>Risk of dilution and CoC for initial shareholders</td>
<td>At conversion:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Provides incentive for shareholders to prevent triggering</td>
<td>Creates incentives for stock price manipulations</td>
<td>Face value = 100</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Higher cost of equity due to high dilution risk</td>
<td>Share price = 25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Received shares: 100/25 = 4</td>
</tr>
<tr>
<td><strong>Below par value</strong></td>
<td>Upon conversion, the bondholder receives an amount of equity capital, which is lower than the face value of the bond.</td>
<td>Higher entity value due to the resulting reduced leverage</td>
<td>Shareholders have an incentive to trigger the coco prematurely (profiting from deleveraging)</td>
<td>Face value = 100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower risk of speculative attacks (by bondholders)</td>
<td>Less incentive to improve risk and capital management</td>
<td>Share price = 25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduced risk of dilution and CoC</td>
<td></td>
<td>Reduced face value = 75</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Received share: 75/25 = 3</td>
</tr>
</tbody>
</table>

\(^{91}\) The conversion ratio is defined as the quotient of the par value and the share price at conversion.
Elements of Contingent Convertible Bonds

| At/below/above market price of coco | At conversion, the bondholder receives an amount of shares, which is equivalent to the market value of the bond. | Lower risk of dilution, since exchanged shares depend on the bond’s market value, which is likely to decrease as equity value declines. | High debt and equity costs due to the increased uncertainty on both sides. | Face value = 100
Share price = 25
Market value = 82.5
Received shares: 87.5/25 = 3.5 |

Table 8: Characteristics of fixed value conversion

The most apparent and discussed conversion ratio is the conversion at par value. Under a conversion at par, bondholders will receive their coco’s face value in shares of the underlying entity and will therefore not bear any losses, provided they sell their shares immediately. The coco bond will thus be converted into equity as if it had been called at par providing coco holders with a very safe claim and thereby reversing the proper subordination hierarchy. The initial shareholders and senior non-coco debt holders would in contrast experience substantial losses in the form of a dilution in share prices. Stock prices on the verge of triggering are assumed to be very low (near zero), since the issuing institution is almost in default. Consequently, the expected dilution among the initial shareholders is estimated to be quite significant. If this dilution takes place at a high rate – in excess of 50% – control over the financial institution could even devolve to the erstwhile coco bondholders. If the fixed value conversion ratio is additionally combined with a high trigger, bondholders could easily take over a bank with a respectable residual value, making a conversion highly attractive for investors. A conversion is fundamentally less attractive if the trigger value is low, leaving bondholders with shares of a bank with little remaining entity value. In the worst case, a

---

92 On the basis of Pazarbasioglu et al., 2011, p. 27-28.
93 McDonald, 2009, p. 5.
95 Since the issuance of new shares usually causes a decrease in the overall share price (Flannery, 2009, p. 18).
96 Pazarbasioglu et al., p. 11.
98 Pitt et al., 2011, p. 10.
conversion ratio of one could lead to infinite dilution or death spirals, which have already been discussed in the previous chapter.\footnote{SLWG, 2009, p. 5.}

Whilst dilution is normally disrelished by shareholders, it is a rather volitional factor from a regulatory point of view. The risk of sharp share price declines or even a CoC prevents shareholders and therewith the bank’s management from gambling too long and rather incentivises them to implement a solid capital structure.\footnote{Pitt et al., 2011, p. 10.}

One possibility to constrain such – from shareholders’ point of view – negative dilution effects, is the implementation of a floor price. A floor price sets a limit to the maximal number of shares that can be issued, thereby narrowing possible dilution effects. Credit Suisse was the first bank to introduce such a floor price in their recent contingent capital offerings. For example, CS’s Tier 2 Buffer Capital Notes “will be converted into a number of Ordinary Shares determined by dividing the principal amount of each Tier 2 BCN by the Conversion price”\footnote{CSGG IV Ltd., 2012, p. 9.}, which is defined as “the greatest of (a) the Reference Market Price of an Ordinary Share ... (b) the Floor Price...”\footnote{CSGG IV Ltd., p. 9.}, with a floor price of 20 CHF.\footnote{CSGG IV Ltd., p. 94.} In the event of a conversion below the floor share price, CS’s coco bonds will no longer convert at, but below par value.

Another major disadvantage of conversion at par value is its sensitivity to manipulation. Given that a fixed value conversion at par offers more shares as share prices decline, bondholders might be tempted to temporarily push the share prices down in order to maximize their payoff.\footnote{SLWG, p. 5.} To give a case in point, consider the situation where the share price of a financial institution is 23 CHF and the trigger is 22 CHF. If the holder of a coco bond with par value 100 could temporarily push the share price to 20 CHF, the bond would be triggered and the bondholder would receive 100/20 = 5 shares. When the price returns to its “normal” level of e.g. 23 CHF, the bondholder realises a risk-free profit of 5 x 23 CHF – 5 x 20 = 15 CHF.\footnote{McDonald, 2009, p. 12.}

Summing up, one can say that conversion at par assures high dilution, which is, on the one hand negative for the initial shareholders, but, on the other hand, provides positive incentives to retain adequate capital ratios.\footnote{Flannery & Perotti, 2011, p. 3.} From a bondholder’s point of view, conversion at par is quite attractive as it simplifies valuation and reduces uncertainty. Investors would therefore
Elements of Contingent Convertible Bonds

not require a sky-high return on these bonds, making coco capital with a par conversion ratio significantly cheaper for issuers.\(^\text{107}\) A final aspect militating in favour of par conversion is a study conducted by Sundaresan and Wang, which ascertained that a coco with a market-based trigger always has to be converted at par in order to prevent multiple equilibriums.\(^\text{108}\)

Yet, the conversion at par is still at a disadvantage concerning its dilution and manipulation possibilities. A possible answer to these negative effects might be provided by below par conversion, which forces bondholders to bear immediate losses upon conversion.\(^\text{109}\) Under this conversion ratio, the received shares will be worth less than the value of the coco bond, which already signifies that the bondholder is overpaying for the shares. For example, consider the same scenario as above, namely a share price of 23 CHF and a trigger of 22 CHF. If the price goes below the limit of 22, the coco bond will be converted. However, unlike under a conversion at par, the bondholder will now not receive the entire 100/22 = 4.5455 shares, but rather e.g. 80/22 = 3.6364 shares, thereby immediately incurring a loss.

Below par conversions shift value from bondholders to shareholders, thereby eliminating the banks’ incentive to sustain a sound capital structure and to manage risk efficiently. Coco bonds with a below par conversion ratio therefore carry a much higher risk of losses for bondholders and are hence a rather expensive form of coco capital.

Since the conversion terms are inclement to coco bondholders, a speculative attack on their part is expected to be implausible. Shareholders on the other hand would profit from a conversion, since it would deleverage the firm and increase the entity value accompanied with a rise in share prices. Conversion under par therefore does not – unlike a conversion at par – represent a punishment to shareholders but rather something desirable. Hence regulators and investors decline this conversion type to the greatest possible extent.

A third possible conversion ratio would evidently be the conversion above par, which has not attracted much attention so far. A conversion ratio above unity causes tremendous dilution upon conversion, thereby shifting value from shareholders to bondholders.\(^\text{110}\) This conversion type is preferred by Pennacchi et al. for their partly different coco instrument, the so-called COERC. The COERC is a coco bond that converts into equity, if and when the market valued leverage ratio passes an previously stipulated threshold. Upon conversion, these coco instruments are turned into equity at a large discount, generating a massive dilution for shareholders. However, the remarkable trait of COERCs is that they provide the initial share-

\(^{108}\) Sundaresan & Wang, 2010, p. 5.
\(^{110}\) McDonald, 2009, p. 5.
holders the option to buy the shares back at conversion price, thereby giving them the opportunity to retain control over the entity.\textsuperscript{111} In this way, the positive incentives to carefully manage capital ratios can be retained, whilst reducing the risk for coco holders, who would most likely be paid out at or even above par. Furthermore, the conversion structure would prevent price manipulations since bondholders – which are the only profiteers from a conversion – will not become shareholders and thus would not profit from their rig.\textsuperscript{112}

So far, the remarks have been restricted to conversion ratios with respect to par value. Yet, there are also experts favouring a conversion predicated on the effective market value of the coco. The great advantage of such a conversion ratio is the discouragement of price manipulation, as coco prices and share prices would probably decline alike. A price distortion would therefore benefit neither shareholders nor bondholders. On the other hand, such a conversion ratio enhances uncertainty amongst both shareholders and bondholders, because neither share prices nor the conversion value are known ex ante. Furthermore, given that the coco bond market is still in its formation phase and daily traded volumes are therefore low, bond- as well as shareholders would have to rely on thinly traded bond prices in the event of conversion, thereby adding further ambiguity to the process.\textsuperscript{113}

### 3.2.2 Fixed number conversion

A coco bond with a fixed number conversion will – upon conversion – be transformed into a previously specified amount of shares.

<table>
<thead>
<tr>
<th>Conversion</th>
<th>Description</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Into a fixed number of shares</td>
<td>Upon conversion, the bondholder receives an amount of shares which equals the value of the bond divided by a previously stipu-</td>
<td>No incentives for manipulation since the share value has already been fixed. Discourages trigger breaching on both sides (conversion is</td>
<td>Valuation uncertainty among bondholders (do not know the exact equity value they would receive upon conversion ex ante) Higher issuing cost</td>
<td>At conversion: Par value = 100 Share price at bond issuance= 25 Received shares:</td>
</tr>
</tbody>
</table>

\textsuperscript{111} Pennacchi et al, 2011, p. 1.
\textsuperscript{112} Pennacchi et al., p. 5.
\textsuperscript{113} Flannery, 2009, p. 15.
In the majority of cases, conversion into a fixed number of shares is based on the par value of the coco bond and the share price at the date of issuance. The conversion ratio is then calculated by the quotient between the par value and the share price.\textsuperscript{115} For example, consider a coco bond with a par value of 100 issued by an institution with a current share price of 20. If this coco bond converts two years later, the holder will receive $100/20 = 5$ shares, even if the share price upon conversion were significantly lower than 20. The great advantage for shareholders is the certainty concerning the dilution upon conversion. Bondholders, on the other hand, are in an inferior position as they will most likely experience losses in the event of conversion and, in addition, are left in the dark about their exact deficit value until the end. This higher loss risk has to be adequately compensated, leading to comparatively high issuing costs of coco capital with fixed number conversion.\textsuperscript{116}

Apparently, identifying the share price at issuance as the conversion price is problematic. As the trigger value is approached, share prices are expected to decline, making it highly likely that the share price at conversion is considerably lower than the conversion price – especially in the case of low-trigger cocos. More often than not, bondholders will experience an immediate loss upon conversion, thereby again shifting value from bondholders to shareholders. This negative share price development is due and should therefore be included in the prices ex ante. One possible approach would be to take a reduced conversion price, e.g. 80% of the price at issuance, or to enhance the conversion ratio’s par value, e.g. 110% of par value divided by the current share price.\textsuperscript{117}

\begin{table}
\centering
\begin{tabular}{|c|c|c|c|}
\hline
\text{lated share price} & \text{only worthwhile if} & \text{of coco capital} & \text{100/25 = 4} \\
\text{the share price is} & \text{the share price is} & \text{(Independent} & \\
\text{sufficiently low)} & \text{of coco capital} & \text{of the} & \\
\text{Shareholders} & \text{such as the} & \text{share’s mar-} & \\
\text{know the delu-} & \text{delusive effect upon} & \text{ket price)} & \\
\text{sive effect upon} & \text{conversion in} & \text{are totally} & \\
\text{conversion in} & \text{advance} & \text{in the} & \\
\text{share’s mar-} & & \text{dark about} & \\
\text{ket price)} & & \text{their exact deficit} & \\
\hline
\end{tabular}
\caption{Characteristics of a fixed number conversion\textsuperscript{114}}
\end{table}

\textsuperscript{114} On the basis of Pazarbasioglu et al., 2011, p. 28-29.
\textsuperscript{115} Von Furstenberg, 2011, p. 21.
\textsuperscript{116} Maes & Schoutens, 2010, p. 12.
\textsuperscript{117} Von Furstenberg, p. 21.
Another approach to define non-discriminatory conversion prices was taken by J.P. Morgan. They combined the two above-mentioned methods and recommended the use of share price conditions at the time of bond issuance in order to project market share prices upon conversion, which would then become the conversion prices for the coco bond. If, for example, the capital ratio at coco issuance were 15% and the trigger level 7%, conversion prices would be set to $7:15=46.7\%$ of the current share price.\footnote{J.P. Morgan, 2011 as cited in Von Furstenberg, 2011, p. 21.}

The greatest advantage of the fixed number conversion is the reduced desirability of share price manipulations. Since the coco conversion ratio is already determined at issuance, bondholders would only harm themselves if they forced share prices down. Granted, management could profit from a manipulation of share prices and the resulting conversion through the avoidance of further interest payments, but even this potentiality only becomes attractive if the costs of the newly issued shares lay below the coupon payments.\footnote{SLWG, 2009, p. 5.}
4 The Model

The market for contingent capital is estimated to reach a size of $1 trillion. Yet, the success of coco instruments will ultimately depend on the investors ability to hold these instruments and hence on the rating agencies willingness to price coco bonds. So far, Fitch was the first rating agency that provided ratings on coco bonds, whilst S&P as well as Moody’s have argued that the conversion risk cannot be assessed and the bonds therefore not be rated. The greatest valuation challenge is presumably the great variety in the design of coco bonds with respect to the trigger, the trigger level and the conversion ratio, as presented in the last chapter. It is therefore exceptionally difficult to create one pricing model that covers all these design options. Figure 3 provides a brief overview of the main factors that have an impact on the value of coco bonds.

There are mainly two questions one needs to answer when modelling a coco, namely how the underlying trigger (CDS spreads, market price, capital ratio) could be modelled and secondly, what the value of the coco is at conversion. Most of the early models have been based on share price triggers. Yet, the financial institutions that have been releasing coco capital so far rather based their triggers on capital ratios. This was soon realised by experts and more practical approaches appeared in the academic literature. The next generation of coco models now focused on the capital

---

The ratio trigger, which was either modelled by a Brownian motion\(^{125}\) or through a derivative approach\(^{126}\).

Given the practical relevance, the objective of this paper is to derive a valuation model for a contingent convertible bond with a capital ratio trigger. The basic coco model will be based on former convertible bond models, whose fundamentals have already been laid in the late 20\(^{th}\) century by Brennan & Schwartz\(^{127}\) and Merton\(^{128}\). More precisely, this paper will focus on a numerical, multiple trees hybrid bond framework, which was invented in 2001 by J.P. Morgan\(^{130}\). This so-called rock-bottom spread model will be used as a basis and will then be extended in order to accurately reflect the particular characteristics of contingent convertible bonds.

The following paragraphs will first introduce the basic rock-bottom spread framework as well as its assumptions and computations, before turning to the extension of the model.

### 4.1 The original model

The rock-bottom spread framework is an eight-state multinomial model for the valuation of hybrid bonds. The model's most important and basic assumptions are 1) that the probability of receiving specific cash flows is contingent on the general financial condition of the underlying institution and 2) that the different financial conditions can be represented by the credit rating of the underlying institution.\(^{131}\) Given that each rating or state represents one financial condition, it is possible to assign the respective cash flows to the different states. For example, a bond with a par value of 100

---


\(^{126}\) De Spiegeleer & Schoutens, 2011.

\(^{127}\) Brennan & Schwartz, 1977.


\(^{129}\) Buergi, p. 12.


\(^{131}\) Henriques, Goulden & Granger, 2006, p. 5.
and a coupon of 5 % would after one year (t=1) result in a cash flow of 105 in all states, apart from the event of a default (in which case the bondholder would receive the recovery value of e.g. 45)(figure 4). Presupposed that we know the probabilities for the different states, the calculation of the expected values as well as the variances of the bond is straightforward. However, the risk-bottom spread model does not primarily aim at discounting future cash flows, but rather focuses on the calculation of the so-called risk bottom prices as well as the risk bottom spreads, which will be introduced in the next section.

4.1.1 Rock-bottom spreads

The rock-bottom spread is the marginal spread (reservation spread) that investors would be requesting in order to be sufficiently compensated for their assumed credit risks. The framework is built on the assumption that investors require a premium for the additional risks involved in such instruments, or more precisely, investors are expected to be risk-averse.132

Given that rock-bottom spreads represent the reservation spreads of an individual investor, they are absolutely independent from market spreads, which are mainly driven by the sentiment of the entire market. Rock-bottom spreads are therefore much better suited to define the fair value of bonds.133 Consequently, by comparing market and rock-bottom spreads, it can easily be determined whether investors are accurately compensated for their risks. If market spreads exceed rock-bottom spreads, the investor is sufficiently compensated for the underlying credit risk. If the difference between the spreads additionally reimburses the bondholder for potential illiquidity risks, the bond is assumed to be fairly valued. In contrast, if rock-bottom spreads surmount market spreads, the investor is not sufficiently compensated for his risk and should therefore not invest in the respective instrument.134 Summing up, the rock-bottom framework can serve as a powerful tool to ascertain whether a bond is fairly valued or not.

4.1.2 Input parameters

A variety of input parameters need to be considered in order to accurately compute rock-bottom spreads and to set up the model.

133 Schaffner, p. 30.
4.1.2.1 Cash flows and rating migration

The basic gist of the rock-bottom framework can best be highlighted with a plain vanilla bond. There are mainly two scenarios an investor needs to consider when calculating the value of a one-year financial bond (see figure 5). In one-year the par value of the bond and the coupon could either be paid back or the issuing financial institution could be in default, thereby leaving the bondholder with nothing but the recovery value. Meanwhile, an investor also has the option to invest in a risk-free bond with a guaranteed cash flow of the par value and the risk-free rate (in our example 100+ 5). As investors can always have a guaranteed return in the amount of the risk-free rate, they will always request a premium for an investment into a financial bond in order to be compensated for the risk of default. The difference in returns, meaning between the risk-free rate and the return of the financial bond, is the so-called spread, which compensates the investor for the additional risk.

The just introduced model is quite useful, as long as the valuation time frame does not exceed one year. However, in the case of multiple years, the financial condition of the issuing institution needs be taken into account as well. As mentioned in the introduction, the rock-bottom framework differentiates eight financial conditions, which are represented by the eight S&P ratings (figure 6).

---

135 On the basis of Rappoport, 2001, p. 8 as cited in Schaffner, 2010, p. 34.
136 This statement is only valid under the previously stated assumption that all investors are risk-averse.
137 Rappoport, 2001b, p. 2 as cited in Schaffner, p. 34.
At each state, the bond has eight distinct development options. The instrument can retain the current rating, upgrade, downgrade or default. In each state the bondholder will receive a certain cash flow of e.g. 8, 45 or 108. Yet, not all states and therefore not all cash flows are equally likely to occur. The probability of e.g. a defaulting BBB bond is much higher than for an A rated bond. This aspect is accommodated for by the so-called rating-migration matrix, which states for each credit rating the likelihood of a rating change (table 10). To give a point in case, a financial institution with a current rating of AA has a 10.13% chance to be downgraded to rating A. Likewise, a BBB rated institution has a probability of 0.48% of being in default in one-year’s time.

<table>
<thead>
<tr>
<th>Rating transition Matrix (adjusted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAA</td>
</tr>
<tr>
<td>AAA</td>
</tr>
<tr>
<td>AA</td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>BBB</td>
</tr>
<tr>
<td>BB</td>
</tr>
<tr>
<td>B</td>
</tr>
<tr>
<td>CCC/C</td>
</tr>
</tbody>
</table>

Table 10: Average one-year Transition Matrix (1981-2011) - Financial institutions

---


The transition matrix enables the weighting of the different outcomes according to their likelihood and the calculation of the expected value as well as the variance in the different states. Yet, since the RBS framework aims at computing the reservation spread given the risk aversion of the investor, a parameter for the investor’s readiness to assume risk must be included in the calculation as well.

### 4.1.2.2 The Sharpe ratio

In the rock-bottom spread framework, the investors’ risk behaviour is represented by the so-called Sharpe ratio, which was invented in 1966 by William F. Sharpe and is a special form of the so-called information ratio. The Sharpe ratio measures the excess return in relation to the taken risk (measured by the standard deviation). Given that this ratio states the risk premium that an investor requires in order to bear the additional risk, it is consummately suitable to represent the investor’s attitude towards risk.

The Sharpe ratio is generally expressed in the form:

\[
SR^{(A)} = \frac{E[r_A - r_f]}{\sqrt{\text{Var}(r_A - r_f)}}
\]

where \(SR\) means Sharpe Ratio, \(r_A\) is the return of the risky asset \(A\) and \(r_f\) the risk-free return. Empirically, the Sharpe ratio value across several asset classes tends to be approximately 0.5, which has become the investment management industry standard. By requesting a certain Sharpe ratio, investors can determine how much excess return they demand for the underlying additional risk.

Equation I states the Sharpe ratio for just one asset. Yet, an investor usually manages portfolios that consist of various asset classes. This large diversification reduces the risk of each individual asset and therefore the standard deviation parameter in the Sharpe ratio equation. In order to adjust the formula to this risk reduction, one can apply the concept of diversity.

---

140 Sharpe, 1966.

141 The Sharpe ratio measures the excess return of a risky asset compared to a risk-free asset, whilst the Information ratio relates the asset’s return to a benchmark.

142 Spremann & Grüner, 2011, s. 5-11.

scores\textsuperscript{144}. These scores assist to obtain the price diversity of a portfolio by dividing the price volatility of a single bond by the square root of the portfolio’s diversity score (d).\textsuperscript{145}

\[ SR^{(A)} = \frac{E[r_A - r_f]}{SD[r_A]} \sqrt{d} \]

(II)\textsuperscript{146}

After having discussed the different properties of the risk-bottom framework, the actual model can now be constructed followed by the calculation of the respective rbs.

### 4.1.3 Computing risk bottom spreads

As already briefly illustrated in figure 6, the rock-bottom tree can now likewise be set up in order to determine the rbs through backwards calculation. The rock bottom spreads will then represent the reservation spread (the lowest spread which fulfils the investors information ratio) at which the investor is still willing to bear the additional risk of the financial bond.\textsuperscript{147}

In the following paragraphs, an exemplary bond will be modelled so as to depict the calculation and the operating method of the rbs framework (table 11). This example is to a large extend based on the example given in J.P. Morgan’s rock bottom spread calculations, though rating migration probabilities have been adjusted in order to indicate the migration probabilities for financial institutions instead of corporations\textsuperscript{149} (Model.xls / sheet “RBS financial institutions_basic”).\textsuperscript{150}

<table>
<thead>
<tr>
<th>Downgrade/upgrade probability</th>
<th>Table 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bond Par Value</td>
<td>100</td>
</tr>
<tr>
<td>Coupon</td>
<td>8 %</td>
</tr>
<tr>
<td>Risk-free rate</td>
<td>Flat 6 %</td>
</tr>
<tr>
<td>Recovery value</td>
<td>45 %</td>
</tr>
<tr>
<td>Sharpe ratio</td>
<td>0.5\textsuperscript{148}</td>
</tr>
<tr>
<td>Diversity score</td>
<td>70</td>
</tr>
</tbody>
</table>

\textbf{Table 11: Basic model input parameters}

---

\textsuperscript{144} The concept of diversity scores has originally been developed by Moody’s. The aim of this concept is to transform a portfolio of correlated exposures into independent exposures. The more diversified a portfolio is, the higher is its diversity score. For example, setting the diversity score equal to 50 corresponds to a portfolio of 300 to 400 assets (AXA Investment Managers, 2007, p.11).

\textsuperscript{145} AXA Investment Managers, p. 11.


\textsuperscript{147} Schaffner, p. 36.

\textsuperscript{148} Investment management industry standard (AXA Investment Managers, p. 11).

\textsuperscript{149} See Appendix 2 and Excel sheet „RBS corporates_basic“ for the corporate model (and differences between the two examples).
Working backwards, the model first computes the rbs for the penultimate year, meaning one year before maturity (T-1). First of all, the expected values $E[x]$ (equation III) as well as the standard deviations $SD[x]$ (equation IV) of the different states at time T-1 are calculated (figure 7). The probabilities for the different states are given by the rating migration matrix and can thus be taken from table 10.

\[
E_{AAA,T-1} = \sum_{i=1}^{S} p_i \mu_{i,T} = \begin{pmatrix} 0.9115 \cdot 108 \\ 0.08 \cdot 108 \\ \vdots \\ 0 \cdot 45 \end{pmatrix} = 108
\]

\[
E_{AA,T-1} = \sum_{i=1}^{S} p_i \mu_{i,T} = \begin{pmatrix} 0.9997 \cdot 108 \\ 0.0003 \cdot 45 \end{pmatrix} = 107.98
\]

\[
E_{CCC,T-1} = \sum_{i=1}^{S} p_i \mu_{i,T} = \begin{pmatrix} 0.8042 \cdot 108 \\ 0.1958 \cdot 45 \end{pmatrix} = 95.66
\]

The respective standard deviations are calculated accordingly:

\[
SD_{AAA,T-1} = \sqrt{\sum_{i=1}^{S} \left[ p_i \mu_{i,T}^2 - \mu_{AAA,T-1} \right]} = \sqrt{\begin{pmatrix} 0.9115 \cdot 108^2 \\ 0.08 \cdot 108^2 \\ \vdots \\ 0.0003 \cdot 45^2 \end{pmatrix}} - 108^2 = 0.00
\]

\[
SD_{AA,T-1} = \sqrt{\sum_{i=1}^{S} \left[ p_i \mu_{i,T}^2 - \mu_{AAA,T-1} \right]} = \sqrt{\begin{pmatrix} 0.9997 \cdot 108^2 \\ 0.0003 \cdot 45^2 \end{pmatrix}} - 107.98^2 = 1.11
\]

Figure 7: Calculating backwards for state T-1

---

The just derived expected values and standard deviations of the respective states represent the basis for computing the rbs. Yet, due to modelling reasons it is easier to calculate the rock-bottom prices first and to compute the yield of maturity based on these prices afterwards.

As already briefly mentioned in the introduction, the rbs is the lowest spread, which still fulfils the investors’ Sharpe ratio. Therefore, the SR now needs to be included in the calculation of the investors’ reservation spreads. The SR has been introduced in Chapter 4.1.2.2 as:

\[
SR^{(A)} = \frac{E[r_A - r_f]}{SD[r_A] / \sqrt{d}}
\]

Given that the variance of the risk-free interest rate is 0, the formula can be further simplified to:

\[
(\text{II'}) \quad SR^{(A)} = \frac{E[r_A - r_f]}{SD[r_A] / \sqrt{d}} = \frac{E[r_A] - r_f}{\sigma_{r_A} / \sqrt{d}} - 1
\]

where \( \mu_{x_A} \) is the expected value of the return and therefore equal to \( \frac{\mu_A}{x_A} - 1 \) (\( \mu_A \) being the expected value of the asset, \( x_A \) being the price of the asset) and \( \sigma_{r_A} \) the variance of the return, which is equal to \( \frac{\sigma_A}{x_A} \) (\( \sigma_A \) being the variance of the asset). If the SR is now fixed at a certain value, the equation can be solved for the price \( x_A \):

\[
SR = \frac{\mu_A - r_f}{\sigma_A / x_A \sqrt{d}} \Leftrightarrow x_A = \frac{\mu_A - SR \cdot \sigma_A / \sqrt{d}}{(1 + r_f)}
\]

The just derived formula provides the following RBP for the different states (\( x = RBP \)):

\[151^{\text{The derivation of the formula can be found in appendix one.}}\]
As mentioned earlier, calculating the yield of the RBP and subtracting the risk-free return results in the rbs. For a bond with a maturity of one year, the yield to maturity can easily be calculated:

\[
RBP = \frac{ParValue + Coupon}{(1 + rbs)} \Leftrightarrow rbs = \frac{ParValue + Coupon}{RBP} - 1
\]

However, the equation becomes rather difficult for higher maturities. For the yield calculation over several years, a numerical approximation is needed. In this paper the yield to maturity is determined with the respective Excel function. Excel ascertains the yield by calculating up to 100 iteration steps. The solution is computed according to the Newton’s method on the basis of the following formula:\textsuperscript{152}

\[
\text{(VI)} \quad \text{Price} = \left[ \frac{\text{Redemption}}{(1 + \text{yield frequency})^{\left( \frac{\text{N} \cdot \text{DCS}}{\text{E}} \right)}} \right] + \left[ \sum_{k=1}^{N \cdot \text{DCS}} \left( \frac{100 \cdot \text{yield frequency}}{\text{E}} \right)^{k-1} \right] - \left( 100 \cdot \frac{\text{yield frequency}}{\text{E}} \right) \cdot \frac{A}{E} \text{153}
\]

Consequently, the rock-bottom spreads for a one-year financial bond amount to:

\[
\text{(VII)} \quad rbs_{\text{AAA}, T^{-1}} = \text{yield}_{\text{RBP}_{\text{AAA}, T^{-1}}} - r_f = 6.0\% - 6.0\% = 0 \text{ bps}
\]

\[
\text{rbs}_{\text{AA}, T^{-1}} = \text{yield}_{\text{RBP}_{\text{AA}, T^{-1}}} - r_f = 6.08\% - 6.0\% = 8 \text{ bps}
\]

\[
\text{\vdots}
\]

\textsuperscript{152} Yield, 2008.
\textsuperscript{153} The acceptation of the abbreviations can be found at the end of this paper.
\( rbs_{CCC,T-1} = yield_{RBP_{CCC,T-1}} - r_f = 21.57\% - 6.0\% = 1557 \text{ bps} \)

The rock-bottom spread framework can now be extended to longer maturities by simply repeating the inductive backwards calculation. The adjusted (adding the coupon) RBPs at time T-1 serve as input parameters for the calculation of the prices at time T-2 (figure 8). The Rating migration matrix does not change and remains as stated in table 10.

![Figure 8: Calculating backwards for state T-2](image)

The RBPs for the state T-2 are therefore calculated as follows:

\[
E_{AAA,T-2} = \sum_{i=1}^{S} p_i \mu_{i,T-1} = \begin{pmatrix}
0.9115 \cdot 109.89 \\
0.08 \cdot 109.81 \\
\vdots \\
0.00 \cdot 45
\end{pmatrix} = 109.88
\]

\[
E_{AA,T-2} = \sum_{i=1}^{S} p_i \mu_{i,T-1} = \begin{pmatrix}
0.41 \cdot 109.89 \\
0.8902 \cdot 109.81 \\
\vdots \\
0.03 \cdot 45
\end{pmatrix} = 109.78
\]

\[
E_{A,T-2} = \sum_{i=1}^{S} p_i \mu_{i,T-1} = \begin{pmatrix}
0.00 \cdot 109.89 \\
0.00 \cdot 109.81 \\
\vdots \\
0.1958 \cdot 45
\end{pmatrix} = 89.10
\]

Correspondingly, the price volatilities are calculated as:

\[
SD_{AAA,T-2} = \sqrt{\sum_{i=1}^{S} [p_i \mu_{i,T-1} - \mu_{AAA,T-1}]^2} = \sqrt{0.9115 \cdot 109.89^2 + 0.08 \cdot 109.81^2 + \vdots + 0.00 \cdot 45^2} - 109.88^2 = 0.05
\]
\[
SD_{AAA,T-2} = \sqrt{\sum_{i=1}^{T} [p_i\mu_{i,T-1} - \mu_{AAA,T-2}]} = \left[ \begin{array}{c} 0.0041 \cdot 109.89^2 + \\ 0.8902 \cdot 109.81^2 + \\ \vdots \\ 0.0003 \cdot 45^2 \end{array} \right]^{1/2} = 109.78^2 = 1.15
\]

\[
SD_{CCC,T-2} = \sqrt{\sum_{i=1}^{T} [p_i\mu_{i,T-1} - \mu_{CCC,T-2}]} = \left[ \begin{array}{c} 0.00 \cdot 109.89^2 + \\ 0.00 \cdot 109.81^2 + \\ \vdots \\ 0.1958 \cdot 45^2 \end{array} \right]^{1/2} = 89.10^2 = 22.15
\]

With the expected value and the standard deviation, the RBPs can again be calculated:

\[
(II') \quad RBP_{AAA,T-2} = \frac{\mu_{AAA,T-2} - SR \cdot \sigma_{AAA,T-2}}{\sqrt{d}} = \frac{109.88 - 0.5 \cdot 0.05}{(1 + 0.06)} = 103.65
\]

\[
RBP_{AAA,T-2} = \frac{\mu_{AA,T-2} - SR \cdot \sigma_{AA,T-2}}{\sqrt{d}} = \frac{109.78 - 0.5 \cdot 1.15}{(1 + 0.06)} = 103.50
\]

\[
RBP_{CCC,T-2} = \frac{\mu_{CCC,T-2} - SR \cdot \sigma_{CCC,T-2}}{\sqrt{d}} = \frac{89.10 - 0.5 \cdot 22.15}{(1 + 0.06)} = 82.81
\]

And finally with the excel price-to-yield calculation, the rbs for point in time T-2 are calculated as:

\[
(VII) \quad rbs_{AAA,T-2} = yield_{RBP_{AAA,T-2}} - r_f = 6.01\% - 6.0\% = 1\ bps
\]

\[
rbs_{AA,T-1} = yield_{RBP_{AA,T-3}} - r_f = 6.09\% - 6.0\% = 9\ bps
\]

\[
\vdots
\]

\[
rbs_{CCC,T-1} = yield_{RBP_{CCC,T-1}} - r_f = 19.13\% - 6.0\% = 1313\ bps
\]

It goes without saying that the rock-bottom framework can be extended to a discretionary time horizon by simply repeating the inductive backward calculation. Table 12 depicts in an exemplary manner the rbs for different maturities, ranging from one to ten years.
The Model

Table 12 and figure 9 display how rock-bottom spreads vary across different credit ratings and maturities. It is notable that the investment-grade ratings (AAA, AA, A and BBB) are all almost linearly upwards sloping, meaning that rbs escalate as maturity increases. This is due to the fact that the risk of default ascends as maturity increases, causing the investor to demand a higher compensation for the assumed risk. The BB rating rbs variations are still upward sloping but with descending steepness, thereby marking a turning point. For B and CCC credit ratings, rbs decrease as maturity increases, as the non-defaulting B and CCC rated financial institution have more upgrade than downgrade potential.

Naturally, rbs also change when the input parameters are adjusted. Consider for example a bond with a maturity of 10 years, a coupon of 8% and a risk free rate of 6%. If the risk-free rate changes to lower/higher levels, rock-bottom spreads tend to slightly increase/decrease. This is due to the fact that the entire rock-bottom framework is predicated on discounted future cash flows. As risk-free rates increase, discounted cash flows as well as rock-bottom

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAA</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>AA</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>A</td>
<td>17</td>
<td>19</td>
<td>20</td>
<td>21</td>
<td>22</td>
<td>23</td>
<td>24</td>
<td>25</td>
<td>26</td>
<td>27</td>
</tr>
<tr>
<td>BBB</td>
<td>55</td>
<td>57</td>
<td>61</td>
<td>61</td>
<td>62</td>
<td>64</td>
<td>65</td>
<td>67</td>
<td>68</td>
<td>69</td>
</tr>
<tr>
<td>BB</td>
<td>117</td>
<td>129</td>
<td>137</td>
<td>143</td>
<td>148</td>
<td>152</td>
<td>154</td>
<td>156</td>
<td>158</td>
<td>159</td>
</tr>
<tr>
<td>B</td>
<td>331</td>
<td>338</td>
<td>339</td>
<td>337</td>
<td>333</td>
<td>328</td>
<td>323</td>
<td>318</td>
<td>314</td>
<td>309</td>
</tr>
<tr>
<td>CCC/C</td>
<td>1557</td>
<td>1313</td>
<td>1137</td>
<td>1007</td>
<td>911</td>
<td>838</td>
<td>781</td>
<td>737</td>
<td>701</td>
<td>671</td>
</tr>
</tbody>
</table>

Table 12: Rock-bottom spreads for a financial bond with different maturities

Figure 9: Changes of rbs across different maturities and ratings
The Model

prices decline in value\textsuperscript{154} leading to smaller rock-bottom spreads.\textsuperscript{155} In contrast, if coupon payments are high/low, rock bottom spreads will increase/decrease as well, since the capital loss in the event of default is much higher for high-coupon bonds and investors demand a higher compensation for this additional risk.\textsuperscript{156,157} The just constructed model serves as a benchmark for the derivation of the extended model, which needs to be adjusted for the main characteristics of coco bonds.

4.2 The adjusted model

As already mentioned in the introduction, the objective of this paper is to derive a valuation concept for coco bonds on the basis of the just explained rock-bottom spread framework. However, as highlighted in Chapter 3, there exist a great variety of coco designs, which cannot be replicated in just one model. It is therefore essential to contain the design possibilities and to focus on one particular variation of contingent capital. Yet, beforehand, the following section will shortly highlight if and how the different predominant design features could be included in the model.

Capital ratio-based trigger

Since it can be assumed that credit ratings and therewith financial conditions of the underlying institution are sufficiently correlated with the respective capital ratios, they can be represented by the different credit ratings and are therefore easily included in the model.

Share price based-trigger

If share prices moved in line with credit ratings, a share price-based trigger could again be replicated by a certain rating. However, since share prices are influenced by a great variety of factors, credit ratings just remain a small driver of many. It can therefore not be assumed that credit ratings can accurately represent share price movements. Stochastic processes as already displayed by Flannery, McDonald and Sundaresan and Wang are much more suitable to approximate the value of such share price-based trigger bonds.

Systemic trigger

A systemic trigger is either based on regulators’ discretion or an index. In both cases, the here-derived framework is not qualified to model these factors, as they are not sufficiently

\textsuperscript{154} But not enough to outweigh the increase in risk-free rates.
\textsuperscript{155} Appendix 2 provides more specific data on the rbs sensitivity with respect to interest rates.
\textsuperscript{156} Schaffner, 2010, p. 42.
\textsuperscript{157} Appendix 2 provides more specific data on the rbs sensitivity with respect to coupon payments.
connected to the individual credit ratings. Whilst a stochastic process could presumably best model an index-based trigger, a trigger based on regulators’ discretion is almost impossible to replicate, since it is not predicated on objective market data.

**Fixed value conversion**

A conversion at/below/above par or market value can be included in the model since the par, as well as the market value of the bond, are given at each point in time.

**Fixed number conversion**

The payoff at conversion depends on the ratio between the share price at the time of issuance and the share price upon conversion. Whilst the share price at issuance is known, the share price upon conversion would again have to be modelled. As already explained earlier, share price developments over times can be estimated more precisely by stochastic processes.

On these grounds, the here derived model will focus on a coco bond with a capital ratio-based trigger and a fixed value conversion. Compared to the original rock-bottom framework, there are mainly two features that need to be included in the adjusted model, namely the trigger point (and the therewith connected conversion) and the callability (as most of the coco bonds issued today include this feature).

### 4.2.1 Conversion

The contingent conversion feature is the predominant factor that distinguishes coco bonds from plain vanilla convertible bonds. This contingency feature particularly influences the lower credit rating area, where financial institutions approach default. In order to define the rating level at which a coco bond will be triggered, it has to be analysed how capital ratios influence credit ratings.

Credit ratings are generally determined by applying the so-called S&P banking rating framework (figure 10). The rating process starts with the definition of the industry and country risk (which is for the majority of sectors and countries around BBB). In a second step, these macro ratings are adjusted predicated on more bank-specific factors, such as business position, capital & earnings, risk position and funding & liquidity. Thus, the capital ratio aspect is one of the four bank-specific factors that can either enhance or

---

158 Furthermore, the derived framework could also be used to compute the value of write-down contingent capital.
decrease a rating. Table 13 provides more details on how ratings are adjusted based on the T1 capital ratio. The table states the different rating changes based on a BBB rated company. If the capital ratio surpassed for example the threshold of 7% (high trigger), the rating would be downgraded by one notch\textsuperscript{159} and accordingly the breaching of the 5% threshold (lower trigger) would lead to a downgrade of two to three notches. A company that started with a higher capital ratio of e.g. 13 % would likewise be downgraded two, respectively three to four notches.\textsuperscript{160}

Yet, the capital ratio decline can certainly not be examined apart from other rating factors. A decrease in capital ratio is just an indication for the overall deterioration of the bank’s financial condition. Hence, it can be assumed that other factors, such as earnings and liquidity would decrease as well. A worsened business as well as an increased risk position would be the aftermath. Therefore, many rating triggers would at once be pushing the rating downward. Under the assumption that a capital ratio decrease to the moderate level (high trigger) would trigger the other three bank-specific factors to worsen as well to moderate/weak levels, a breaching of the 7% threshold would re-

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure10.png}
\caption{S&P’s Banking rating framework\textsuperscript{161}}
\end{figure}

\begin{table}[h]
\begin{center}
\begin{tabular}{|l|c|c|}
\hline
Qualifier & Capital ratio & Adjustment \\
\hline
Very strong & > 15\% & + 2 notches \\
Strong & 10\% - 15\% & + 1 notch \\
Adequate & 7\% - 10\% & 0 notches \\
Moderate & 5\% - 7\% & -1 notch \\
Weak & 3\% - 5\% & -2 to -3 notches \\
Very weak & < 3\% & -5 notches \\
\hline
\end{tabular}
\end{center}
\caption{Capital ratio rating adjustments\textsuperscript{162}}
\end{table}

\textsuperscript{159} One notch is defined as a small rating change, as for example from BBB to BBB-. \\
\textsuperscript{160} As its capital ratio state deteriorated from strong to moderate. \\
\textsuperscript{161} On the basis of S&P, 2011, p. 6. \\
\textsuperscript{162} On the basis of S&P, p. 13, 22.
sult in a total downgrade of approximately six notches\textsuperscript{163} for a BBB rated company (to B), nine notches\textsuperscript{164} for an A rated company (to B) and so on.\textsuperscript{165} It stands to reason that a direct drop from e.g. A to CCC/C or D would also cause a conversion, since it just represents a more than required decline of the capital ratio and the financial condition. In the case of a low trigger coco, the capital ratio would have to decrease to the weak level (below 5 %), thereby again presumably forcing the other bank-specific factors to deteriorate as well. If they also decrease to the weak level, the credit rating would approximately be downgraded 9 notches for a BBB rated institution (to CCC), 12 notches for an A rated institution (to CCC) and so on. It can therefore be concluded, that a high trigger coco can be represented by a rating downgrade to B, a low trigger coco likewise by a downgrade to CCC/C (figure 11).

After defining the trigger rating, the exact conversion value is the next feature that needs to be included in the model. Upon conversion, coco capital will be turned into shares with a certain value (above/below or at par/market value). Under a conversion at par, for example, the coco holders would receive their par value in shares of the issuing institution. If investors keep their shares, they become usual shareholders and share price models would now be needed in order to accurately represent the value of the investment. However, for the objective of this model, it is most accurate to treat conversion as an early redemption at par.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{conversion_concept}
\caption{Exemplary construction of the conversion concept}
\end{figure}

\textsuperscript{163} E.g.: -1 (capital ratio: adequate => moderate)+ -1 (liquidity: adequate => moderate)+-2(business position: adequate => weak)+-2(risk position: adequate => weak) = -6.
\textsuperscript{164} E.g.: -2 (capital ratio: strong => moderate)+-1(liquidity: strong => moderate)+-3(business position: strong => moderate)+-3(risk position: strong => moderate)= -9.
\textsuperscript{165} For more details on how rating changes as the other three bank-specific factors change, see appendix 3.
First of all, at conversion, each investor has the possibility to realize the payoff of his bond by selling the shares in the market. Upon conversion, it is therefore absolutely accurate to define the value of the bond equal to the par value.

Secondly, investors can mainly be divided into two groups, namely fixed income and equity investors, out of which the first group is presumably the main stakeholder of coco capital. Yet, these fixed income investors probably have no use for shares and would therefore try to dispose of them as quickly as possible. Additionally, most traditional fixed income investors operate under fund managements, which prohibit them from equity investments. Admittedly, it is still not known whether this interdiction will just force the selling of equity upon conversion or actually prevent fixed income investors from even buying these assets in the first place. Over the next years, these fund mandate regulations are expected to evolve, thereby leading to a clarification of this issue.

A final important reason for treating a conversion at par as an early redemption is the model itself. The here-derived framework has been constructed in order to accurately depict bond features. Yet, as already explained in the introduction, share price developments could only be fairly depicted if they were strongly correlated to the credit ratings, which they are not. In other words, the rock-bottom framework has been constructed to value bonds and since – after conversion – there are no bonds left to value, the model reached its limits.

On these grounds, this framework will model conversion as a final payoff.

For example, consider a bond with a par value of 100 and a below/above par conversion ratio. Upon conversion this bond would convert into 90%/110% of its par value, or respectively 90/110. A conversion at market price is now also easy to model by just taking the discounted expected value of the bond at the time of conversion as conversion value.

An additional aspect that needs to be considered is the share price stability upon conversion. It might be true that investors receive e.g. their par value of 100 at conversion, but due to the negative signalling effects that conversions are expected to have, accompanied by rapid share price declines, they might not be able to sell all shares at the conversion price. In addition, the fact that many investors will simultaneously try to sell their shares will put further downward pressure on stock prices. Since negative signalling effects amplify as ratings decline, it can be assumed that share price drops increase in size as capital ratio triggers decrease. In other words, the investor's actually realized conversion value will presumably deteriorate as ratings decline. A conversion at B level will therefore still have a higher pay off.

166 Brahmi, 2011, p. 6.
than at CCC/C or even D level. Since there have not been any conversions so far, it is hard to estimate how fast share prices will actually decline as they approach conversion.

One possible scenario: At a conversion at B level, the financial condition of the underlying institution is still moderate, and share prices are therefore not expected to decline by more than 5%. A conversion at CCC/C level implies a weak to very weak financial condition of the underlying institution. This situation is similar to the one at the end of 2008, where many banks were facing difficulties and had to report inter-day stock price declines of more than 10%. A conversion at CCC/C level is therefore expected to result in a conversion value of approximately 90% of par value. Yet, since the available data is not sufficient to make these assumptions and the differences in rock bottom spreads are not crucial (table 14), the adjusted model will assume that the exchanged equity value can be entirely realized upon conversion.

The final issues that needs be resolved in order to adequately model the conversion aspect is the default case. In the event of default, a usual bondholder would receive the recovery value of the bond. Yet, as coco investors will turn into shareholders before the institution enters default, they would receive their fraction of the bankruptcy estate

<table>
<thead>
<tr>
<th>Rock-bottom spreads cocos</th>
<th>Reduced conversion value</th>
<th>100% conversion value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAA</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>AA</td>
<td>24</td>
<td>23</td>
</tr>
<tr>
<td>A</td>
<td>45</td>
<td>44</td>
</tr>
<tr>
<td>BBB</td>
<td>113</td>
<td>107</td>
</tr>
<tr>
<td>BB</td>
<td>242</td>
<td>214</td>
</tr>
</tbody>
</table>

*Table 14: Reduced vs. fixed conversion value rbs*

---

168 Calculated for a bond with a coupon of 8% under the assumption of a risk-free rate at 6%.

(which is most likely equivalent to zero).\textsuperscript{170} It is important to notice that in this model the event of a downgrade from e.g. BB to D means that the capital ratio breach and the default are taking place simultaneously, thereby leaving no time for coco investors to sell their shares.

After having incorporated the conversion feature into the rock-bottom framework (as summarized in figure 12), the following section will now explain how the callability aspect, which is not directly a characteristic of coco bonds but rather of hybrid bonds in general, can be included into the model.

\textbf{4.2.2 Callability}

The decision whether to call a bond or not, is again dependent on a variety of factors, such as overall conditions of the credit market, LIBOR rates and the credit quality of the issuing institution. At the end of the call period, the issuing institution will ask itself whether it is more expensive to extend the current coco (which usually includes a step up in the interest rates) or to issue a new bond. In other words, if the issuer can refinance the initial bond to better conditions, the coco bond will be called and a new instrument will be issued. If either future market spreads or LIBOR rates decrease or if the financial condition of the institution enhances, bonds will rather be refinanced. The rating migration matrix implies the future condition of the issuing institution and could therefore be used as a trigger. For example, consider a financial institution with an A rating and an outstanding coco bond which is callable in five years. If the institution is downgraded by the end of the call period, the worsened financial condition will lead to higher refinancing costs thereby turning the extension of the bond despite the step up into the more profitable option. Likewise, a rating upgrade would lead to an improved financial condition thereby lowering refinancing costs and leading to the call of the bond. The call trigger can therefore be fixed either above or at (depending on the assumed general interest rate development\textsuperscript{171}) the current rating.\textsuperscript{172}

Figure 13 depicts how the call trigger is incorporated into the model. The exemplary tree has been created for a financial institution with a current credit rating of A. The call trigger has been set at AA due to the presently extremely low interest rate levels and the anticipated increase in credit spreads for the coming years.

\textsuperscript{170} This assumption is further supported by Henriques et al., 2006, p. 10 who already estimate a recovery of 0 for Tier 1 capital.

\textsuperscript{171} If overall LIBOR rates are expected to increase, the call trigger would be set one notch above the current rating. Likewise, stable or declining LIBOR rates would lead to a trigger fixing at the current rating level.

\textsuperscript{172} Henriques et al., p. 14-17.
Figure 13: Exemplary coco bond with a call option
5 Pricing financial Cocos

The rock-bottom framework has now been adjusted for the conversion as well as for the callability aspect. With the extended model it is now possible to estimate the fair spread that investors are willing to pay for contingent convertible bonds. As already explained in the introduction, the adjusted rock bottom framework has been derived in order to value coco bonds but is also quite suitable to value other contingent products such as the write-off bond. Certainly, it would be quite interesting to apply the model to a number of instruments, but since there have only been a few issuances so far, this chapter will display the valuation process with two recently issued contingent capital products as an example. The derived rock-bottom spreads will then ultimately be compared to the respective market spreads in order to evaluate whether these products are fairly valued or not. All calculations from the following chapter can be reproduced with the respective Excel file “Pricing.xls”.

5.1 Calibrating the model

The two instruments that have been chosen to test the extended model are the CS Buffer Capital Note, which was issued on March 22, 2012 and the UBS Tier 2 capital note, which was issued on February 22, 2012. The CS bond represents a genuine coco bond with a high capital ratio trigger and a conversion at par. The relevant terms and conditions of the BCN are as follows:

<table>
<thead>
<tr>
<th>Issue Price</th>
<th>101 % of principal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issue Date</td>
<td>22.03.2012</td>
</tr>
<tr>
<td>First (and only) early redemption date</td>
<td>22.03.2017</td>
</tr>
<tr>
<td>Maturity Date</td>
<td>22.03.2022</td>
</tr>
<tr>
<td>Interest Basis</td>
<td>Fixed rate 7.125 % p.a. paid annually</td>
</tr>
<tr>
<td>Redemption/Payment basis</td>
<td>100% of principal amount</td>
</tr>
<tr>
<td>Interest rate after extension</td>
<td>5-year CHF mid market swap rate + 6.685%</td>
</tr>
<tr>
<td>Conversion trigger</td>
<td>T1 Capital ratio &lt; 7%</td>
</tr>
<tr>
<td>Conversion ratio</td>
<td>Fixed amount conversion (if share price &gt; 20 CHF)</td>
</tr>
</tbody>
</table>

*Table 15: Credit Suisse T2 BCN Terms & Conditions*
These key parameters have to be construed before they can serve as input data for the rock-bottom model. The issue price is not directly relevant for the model but will later be needed to calculate the BCN’s market spread. The issue dates provide the exact maturity of the bond, namely 10 years and the time to call, which in this case is 5 years. The coupon or interest payments – for the time before call – can simply be copied into the model. Yet, the coupon for the after call period depends on the CHF ISDAFIX mid market swap rate on the call date, which is still unknown today. In order to estimate the after-call coupon rate as accurately as possible, the CHF ISDAFIX MMS rate on March 22, 2017 is approximated by the CHF 5-year ISDAFIX MMS forward rate. The sum of the forward rate and the step up of 6.685 % provides the coupon rate for the after-call period.

For the determination of the correct call trigger, the future credit market needs to be evaluated. The currently extremely low interest rate levels lead to an anticipated increase over the next years. Meanwhile, the coco bond market will probably abate its illiquidity and uncertainty thereby promoting a decrease in interest rates. These two developments are expected to cancel each other out, thereby militating in favour of a call trigger at the current rating (A).

Since the BCN’s conversion trigger is set at the high level, the respective trigger in the extended model will be at B level. The conversion value is basically equal to the par value. Credit Suisse additionally included a floor price to prevent unlimited dilution upon conversion. If the share price at conversion is below 20 CHF, coco bondholders will not receive their complete par value but

\[
\frac{ParValue}{20} \text{ number of shares}.
\]

However, as displayed by the Share price chart (figure 14), CS’s stock price did not undercut the value of 20 throughout the last 5 years (not even during the financial crisis). The share is currently at its lowest point since 1993\(^{175}\) and therefore highly likely

![Figure 14: CSGN.VX price chart\(^{174}\)](chart)

\(^{173}\) CSGG IV Ltd., 2012.

\(^{174}\) On chart, based on data from Yahoo! Finance.

\(^{175}\) Thomson Reuters, 2012.
to increase over the next years, further reducing the probability of a price decline below the 20 CHF level. The conversion value will therefore be set equal to the par value.

The rock-bottom model is highly dependent on the rating-transition matrix. There are generally two different rating matrices, which could be applied, namely the 8-state (table 10) or the 18-state transition matrix (appendix 5). While the 18-state migration matrix enables the model to calculate the rbs much more precisely, it also causes a higher number of errors.

Due to historical anomalies, there exist a couple of inconsistencies regarding the transition probabilities. For example, a B rated company is more probable to default than a B-rated institution and likewise a BB rated company defaults with a probability of 0.83%, whilst the better-rated BB+ is much likelier to default with a probability of 1.27%. These anomalies distort the calculations and must therefore be prevented. The 8-state transition matrix is much less susceptible to these distortions and is hence the preferred option.

Table 16 summarizes the respective BCN input parameters that are entered into the model.

<table>
<thead>
<tr>
<th>Current Rating</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downgrade/upgrade probability</td>
<td>Average one-year Transition Matrix (1981-2011) - Financial institutions(^{176}) (table 10)(^{179})</td>
</tr>
<tr>
<td>Bond Par Value</td>
<td>5000 CHF</td>
</tr>
<tr>
<td>Maturity</td>
<td>10 years</td>
</tr>
<tr>
<td>Call</td>
<td>5 years</td>
</tr>
<tr>
<td>Call trigger</td>
<td>A</td>
</tr>
<tr>
<td>Coupon (before call)</td>
<td>7.125 %</td>
</tr>
<tr>
<td>Coupon (after call)</td>
<td>1.7966(^{180}) + 6.685 = 8.4816%</td>
</tr>
<tr>
<td>Risk-free rate</td>
<td>Flat 0.92(^{181})</td>
</tr>
</tbody>
</table>

\(^{176}\) Henriques et al., 2006, p. 41.

\(^{177}\) The calculations have been made twice per case (once with the 8-state and once with the 18-state rating migration matrix) see Excel sheet: RBS_CS_CoCo_8 / RBS_CS_CoCo_18 / RBS_UBS_CoCo_8 / RBS_UBS_CoCo_18.


\(^{179}\) The rbs have been calculated twice, once with the 8-state and once with the 18-state. Due to some historical anomalies, the rating migration matrix.

\(^{180}\) 5 year CHF ISDA forward rate. Appendix 4 provides the detailed calculation.

### Table 16: CS model input parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recovery rate</td>
<td>0 %</td>
</tr>
<tr>
<td>Sharpe ratio</td>
<td>0.5\textsuperscript{182}</td>
</tr>
<tr>
<td>Diversity Score</td>
<td>70</td>
</tr>
<tr>
<td>Conversion trigger</td>
<td>B</td>
</tr>
<tr>
<td>Conversion value</td>
<td>100</td>
</tr>
</tbody>
</table>

The respective model and calculations can be found in the Excel sheet “RBS_CS_CoCo_8”.

By inserting the input parameters from above, the model calculates a 10-year A-level rock-bottom spread of 284 bps.

The UBS T2 Subordinated Notes are a perfect example for contingent capital with a low trigger and a write-down option. Table 17 displays the relevant terms and conditions of the bond:

### Table 17: UBS T2 SN Terms & Conditions\textsuperscript{183}

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issue Price</td>
<td>100 % of principal</td>
</tr>
<tr>
<td>Issue Date</td>
<td>22.02.2012</td>
</tr>
<tr>
<td>First (and only) early redemption date</td>
<td>22.02.2017</td>
</tr>
<tr>
<td>Maturity Date</td>
<td>22.02.2022</td>
</tr>
<tr>
<td>Interest Basis</td>
<td>Fixed rate 7.25 % p.a. paid annually</td>
</tr>
<tr>
<td>Redemption/Payment basis</td>
<td>100% of principal amount</td>
</tr>
<tr>
<td>Interest rate after extension</td>
<td>5-year USD mid market swap rate + 6.061%</td>
</tr>
<tr>
<td>Conversion trigger</td>
<td>T1 Capital ratio &lt; 5%</td>
</tr>
<tr>
<td>Conversion ratio</td>
<td>100% Write off upon conversion</td>
</tr>
</tbody>
</table>

\textsuperscript{182} Investment management industry standard (AXA Investment Managers, 2007, p. 11).

\textsuperscript{183} UBS AG, 2012, p. 9 – 11.
These key parameters again have to be construed before they can serve as input data for the rock-bottom model. The issue date is not directly relevant for the model, but will later be needed to calculate the SN’s market spread. The issue dates provide us with the exact maturity of the bond, namely 10 years and the time to call, which in this case is 5 years. The coupon or interest payments – for the time before call – can simply be copied into the model. Yet, the coupon for the after-call period needs to be estimated by the 5-year USD ISDAFIX MMS forward rate. The sum of the forward rate and the step up of 6.061% provides the coupon rate for the after-call period. For the same reasons already stated above, the call trigger will be set equal to UBS’s current S&P rating which is A. Since the SN’s conversion trigger is set at the low level, the respective trigger in the extended model will be at the CCC/C level. The conversion value is 0 due to the bond’s 100% write off feature.

Table 18 summarizes the respective BCN input parameters that are entered into the model.

<table>
<thead>
<tr>
<th>Current Rating</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downgrade/upgrade probability</td>
<td>Average one-year Transition Matrix (1981-2011) - Financial institutions(^{184}) (table 10)(^{185})</td>
</tr>
<tr>
<td>Bond Par Value</td>
<td>100 CHF</td>
</tr>
<tr>
<td>Maturity</td>
<td>10 years</td>
</tr>
<tr>
<td>Call</td>
<td>5 years</td>
</tr>
<tr>
<td>Call trigger</td>
<td>A</td>
</tr>
<tr>
<td>Coupon (before call)</td>
<td>7.25 %</td>
</tr>
<tr>
<td>Coupon (after call)</td>
<td>3.0547(^{186}) + 6.061 = 9.1157%</td>
</tr>
<tr>
<td>Risk-free rate</td>
<td>Flat 2.1%(^{187})</td>
</tr>
<tr>
<td>Recovery rate</td>
<td>0 %</td>
</tr>
<tr>
<td>Sharpe ratio</td>
<td>0.5(^{188})</td>
</tr>
</tbody>
</table>

\(^{185}\) The rbs have been calculated twice, once with the 8-state and once with the 18-state due to some historical anomalies, the rating migration matrix.
\(^{186}\) 5 year US$ ISDA forward rate. Appendix 4 provides the detailed calculation.
\(^{188}\) Investment management industry standard (AXA Investment Managers, 2007, p. 11).
Diversity Score | 70  
| Conversion trigger | CCC/C  
| Conversion value | 0 (100 % Write off)

Table 18: UBS model input parameters

The respective model and calculations can be found in the Excel sheet “RBS_UBS_CoCo_8”.

By inserting the input parameters from above, the model calculates a 10-year A-level rock-bottom spread of 266 bps. Comparing the UBS rbs of 266 bps to the CS rbs 284 bps nicely demonstrates the earlier explained yield difference between high (CS) and low (UBS) trigger cocos. The low trigger is much less likely to be surpassed (due to the additional high-trigger contingent capital\(^{189}\)), and the low-trigger investors therefore require less return as compensation for their assumed risk.

### 5.2 Rock-bottom vs. market spreads

The introduction of the rock-bottom framework highlighted that the rock bottom spreads are quite suitable to define the “correct” value of the bond. This fairness is achieved through the rbs’ independence from market spreads. As mentioned earlier, the rbs provide the lowest spread (reservation spread) at which an investor would still be willing to buy the respective asset. By comparing these rbs to the current market spreads it is possible to evaluate whether an investment into a certain bond is recommendable or not.

The rbs of the CS coco is 284 bps compared to a current market spread of 606\(^{190}\) bps. Figure 15 displays possible explanations for the great difference between market and rock-bottom spreads.

As already mentioned various times, there have not been many contingent

---

\(^{189}\) Due to the Swiss finish regulations SIFIs are expected to build up a total of 3% of RWA with high-trigger contingent capital.

\(^{190}\) Bloomberg, 2012a.
capital issuances so far and only an even smaller part is publicly traded, making it reason-
able to assume that investors require a premium for the illiquidity of the product. A second
aspect is the uncertainty that comes with coco products. Since neither investors nor issuers
have any experience with these instruments, pricing is still not elaborated. This aspect to-
gether with the thin investor base (many funds have still not decided whether to invest in
these instruments or not) pushes prices to extremely high levels that are not justified by the
actual risk of these instruments.

Of course, it might also be true that the model is missing some important aspects. One could,
e.g. argue that the conversion is modelled too optimistically by assuming a complete pay off
at par. If that were true, the UBS bond’s rbs would have to be much closer to the market
spreads (since there is no conversion aspect to “mismodel”). However when comparing the
UBS rbs of 266 to the respective market spread of 515 bps\textsuperscript{191} one has to admit that the dif-
ference is not that much lower\textsuperscript{192}. That is to say, the difference in spreads can only to a small
extent be explained by possible conversion modelling faults. Yet, the mentioned illiquidity
and uncertainty premiums seem to deliver much more reasonable explanations. This argu-
ment is further supported by the fact that the CS BCN has on average traded around
101.524 CHF (597 bps)\textsuperscript{193}, thereby implying that the bond might have been underpriced.

The here-derived model does of course focus more on the fixed income aspects of coco
bonds, which might lead to a neglect of the equity aspects of the instruments. The last chap-
ter will therefore summarise the main advantages and disadvantages of the extended rock-
bottom framework.

### 5.3 Model critics

The model’s greatest advantage is its pure dependency on future cash flows. This provides
the possibility to adjust the framework to a variety of fixed income instruments (as for exam-
ple conversion and callability features). Furthermore, the model is predicated mainly on only
two assumptions, namely 1) that the probability to receive a certain cash flow is linked to the
issuer’s financial condition and 2) that the underlying financial condition can adequately be
represented by credit ratings.\textsuperscript{194} Yet, the literature differs with respect to the ability of credit
ratings to serve as pricing indications.\textsuperscript{195} Credit rating price mechanisms have the advantage

\textsuperscript{191} Bloomberg, 2012b.
\textsuperscript{192} 322 bps vs. 249 bps difference.
\textsuperscript{193} Bloomberg 2012a.
\textsuperscript{194} Henriques et al., 2006, p. 5.
\textsuperscript{195} John, Ravid & Reisel, 2010, p. 489-490.
of conveniently providing one parameter that expresses a large variety of factors. This advantage is at the same time also the largest disadvantage. Especially in the derived extended rock-bottom framework it is questionable whether credit ratings are actually able to represent capital ratio developments. Since credit ratings are impacted by various factors, it is hard to determine how much a capital ratio decline could actually influence these ratings. Table 19 further highlights that aspect by displaying how the capital ratio triggers (B & CCC/C) are rather unlikely to occur from a rating migration matrix angle.

It could be assumed that the probability of a capital ratio triggering is much higher than implied by the small probabilities of B and CCC/C ratings. It might therefore be necessary to adjust the rating migration matrix in order to properly reflect the likelihood of a trigger event.

Finally, when it comes to the valuation of coco bonds, it would be very useful to incorporate share price movements. Since the stock price development can have a significant influence on the value of coco products, a model that is able to link share price and credit quality developments would significantly improve the quality of the valuation framework. As coco issuance gains popularity, an increasing number of data will become available that might help to correct the shortcomings of the rock-bottom framework.

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>CCC/C</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAA</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>AA</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>A</td>
<td>0.07</td>
<td>0.01</td>
</tr>
<tr>
<td>BBB</td>
<td>0.68</td>
<td>0.08</td>
</tr>
<tr>
<td>BB</td>
<td>6.05</td>
<td>1.11</td>
</tr>
</tbody>
</table>

Table 19: Probabilities for capital ratio triggers

---

6 Conclusion

The financial crisis highlighted the major flaws in the Basel II minimum capital requirements, and regulators were fast to react by inter alia introducing contingent capital as one way of crisis prevention. While regulators dispatched these new regulations, the market was not able to keep up. There have been only a couple of coco issuances so far and the pricing procedure is still rather unsteady. The model in this paper therefore aimed at deriving a market-independent value for coco bonds. The framework clearly emphasizes the fixed income features of cocos since it is predicated on a hybrid bond model. However, the conversion, as well as the callability aspect have been included into the model in order to accurately reflect the equity aspects of these instruments. The framework could finally be applied to two recent contingent capital products, thereby determining the fair value of these instruments. The comparison of the rock-bottom spreads with the market spreads pointed out that cocos are highly recommendable as they pay a large premium on the reservation spread. This premium compensates the investors for the illiquidity as well as the uncertainty that comes with these products.

It stands to reason that the here-derived model could be improved in numerous ways. It would for example be much more accurate to use the 18-state rating migration matrix instead of the 8-state matrix. However, as already pointed out in Chapter 5, the 18-state transition matrix contains many historical anomalies, which distort the model’s results. Eliminating these flaws would allow a more precise calculation of the rock-bottom spreads.

Another possible improvement is the amount of states. When valuing coco bonds there are mainly two states one needs to consider, namely conversion and no conversion. If it were possible to determine the probability of a capital ratio threshold-triggering event, one could replicate a simplified model that would presumably improve the accuracy of the calculated rock-bottom spreads.

The share price development is the missing aspect that cannot be replicated by the model. The problem lies within the lacking correlation between credit ratings and share prices, which makes it impossible to include share price developments into the model. Over the years, it might be possible to collect data that provide proof of some analogies between the T1 capital ratio and share price movements, which would then facilitate an extension of the current model. Another aspect, which will have to be priced at some point, is regulatory discretion. As all contingent capital products are obligated to have some sort of regulatory trigger, these design factor need to be considered in future pricing models. As before, observations over a longer period of time might provide more data on when and how exactly regulators will exercise their right to trigger.
As there have not been many contingent capital issuances so far, it was impossible to compare a large variety of instruments with regard to their characteristics and pricing features. As soon as more contingent capital issuances have taken place and a broader variety of data is available, the comparison of different contingent bonds would certainly be an interesting research field for subsequent studies.
References


References


References


References


## Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Number of days from the beginning of the interest date to the redemption date</td>
</tr>
<tr>
<td>BCN</td>
<td>Buffer Capital Note</td>
</tr>
<tr>
<td>C</td>
<td>Coupon</td>
</tr>
<tr>
<td>CoC</td>
<td>Change of Control</td>
</tr>
<tr>
<td>Coco</td>
<td>Contingent convertible</td>
</tr>
<tr>
<td>COERC</td>
<td>Call Option Enhanced Reverse Convertible</td>
</tr>
<tr>
<td>CS</td>
<td>Credit Suisse</td>
</tr>
<tr>
<td>CSGG IV Ltd.</td>
<td>Credit Suisse Group (Guernsey) IV Limited</td>
</tr>
<tr>
<td>DSC</td>
<td>Number of days between the purchase of the bond and the first coupon payment</td>
</tr>
<tr>
<td>E</td>
<td>Number of days of the interest period</td>
</tr>
<tr>
<td>LIBOR</td>
<td>London Interbank Offered rate</td>
</tr>
<tr>
<td>MMS</td>
<td>Mid Market Swap rate</td>
</tr>
<tr>
<td>N</td>
<td>Number of the days between the purchase of the bond and the redemption</td>
</tr>
<tr>
<td>PV</td>
<td>Par Value</td>
</tr>
<tr>
<td>RBP</td>
<td>Rock-bottom price</td>
</tr>
<tr>
<td>rbs</td>
<td>Rock-bottom spreads</td>
</tr>
<tr>
<td>RWA</td>
<td>Risk-weighted Assets</td>
</tr>
<tr>
<td>S&amp;P</td>
<td>Standard and Poor's</td>
</tr>
<tr>
<td>SIFI</td>
<td>Strategically important financial institutions</td>
</tr>
<tr>
<td>SLWG</td>
<td>Squam Lake Working Group on Financial Regulation</td>
</tr>
<tr>
<td>SN</td>
<td>Subordinated Notes</td>
</tr>
<tr>
<td>SR</td>
<td>Sharpe Ratio</td>
</tr>
<tr>
<td>T1</td>
<td>Tier 1</td>
</tr>
<tr>
<td>T2</td>
<td>Tier 2</td>
</tr>
</tbody>
</table>
Appendices

Appendix 1

Derivation of II’

\[
SR = \frac{\mu_A - 1 - r_f}{\sigma_A} \quad \iff \quad SR = \frac{\mu_A - 1 - r_f}{\frac{\sigma_A}{\sqrt[1+r_f]{d}}} 
\]

\[
\iff \quad SR = \frac{\mu_A \cdot \sqrt[1+r_f]{d} - x_A \cdot \sqrt[1+r_f]{d} - r_f \cdot x_A \cdot \sqrt[1+r_f]{d}}{\sigma_A} \quad \iff \quad SR = \frac{\mu_A \cdot \sqrt[1+r_f]{d} - x_A \cdot \sqrt[1+r_f]{d} - r_f \cdot x_A \cdot \sqrt[1+r_f]{d}}{\sigma_A} 
\]

\[
\iff \quad SR \cdot \sigma_A = \mu_A \cdot \sqrt[1+r_f]{d} - x_A \cdot \sqrt[1+r_f]{d} - r_f \cdot x_A \cdot \sqrt[1+r_f]{d} \quad \iff \quad SR \cdot \sigma_A = \mu_A \cdot \sqrt[1+r_f]{d} = x_A \left(\sqrt[1+r_f]{d} - r_f \cdot \sqrt[1+r_f]{d}\right) 
\]

\[
\iff \quad x_A = \frac{\mu_A \cdot \sqrt[1+r_f]{d}}{\sqrt[1+r_f]{d}(1 + r_f)} \quad \iff \quad x_A = \frac{\mu_A \cdot SR \cdot \frac{\sigma_A}{\sqrt[1+r_f]{d}}}{(1 + r_f)} 
\]

Appendix 2

For a 10-year bond with a coupon of 8%:

<table>
<thead>
<tr>
<th>Interest rates</th>
<th>1%</th>
<th>2%</th>
<th>3%</th>
<th>4%</th>
<th>5%</th>
<th>6%</th>
<th>7%</th>
<th>8%</th>
<th>9%</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAA</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>AA</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>A</td>
<td>29</td>
<td>29</td>
<td>28</td>
<td>28</td>
<td>28</td>
<td>27</td>
<td>27</td>
<td>27</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>BBB</td>
<td>73</td>
<td>73</td>
<td>72</td>
<td>71</td>
<td>70</td>
<td>69</td>
<td>68</td>
<td>67</td>
<td>66</td>
<td>65</td>
</tr>
<tr>
<td>BB</td>
<td>169</td>
<td>167</td>
<td>165</td>
<td>163</td>
<td>159</td>
<td>156</td>
<td>153</td>
<td>150</td>
<td>147</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>333</td>
<td>329</td>
<td>324</td>
<td>320</td>
<td>315</td>
<td>309</td>
<td>303</td>
<td>297</td>
<td>290</td>
<td>283</td>
</tr>
<tr>
<td>CCC/C</td>
<td>741</td>
<td>729</td>
<td>716</td>
<td>702</td>
<td>687</td>
<td>671</td>
<td>654</td>
<td>636</td>
<td>617</td>
<td>597</td>
</tr>
</tbody>
</table>

*Table 20: Rbs sensitivity with respect to interest rate changes*\(^{197}\)

\(^{197}\) Own calculations (Model.xls / sheet / RBS financial_sensivity) on the basis of Rappoport, 2001b, p. 7 as cited in Schaffner, 2010, p. 42.
**Figure 16:** Rbs sensitivity with respect to interest rate changes

<table>
<thead>
<tr>
<th>Coupon rates</th>
<th>1%</th>
<th>2%</th>
<th>3%</th>
<th>4%</th>
<th>5%</th>
<th>6%</th>
<th>7%</th>
<th>8%</th>
<th>9%</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAA</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>AA</td>
<td>12</td>
<td>12</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>14</td>
<td>14</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>A</td>
<td>22</td>
<td>23</td>
<td>24</td>
<td>25</td>
<td>25</td>
<td>26</td>
<td>27</td>
<td>27</td>
<td>28</td>
<td>29</td>
</tr>
<tr>
<td>BBB</td>
<td>52</td>
<td>55</td>
<td>58</td>
<td>61</td>
<td>63</td>
<td>66</td>
<td>68</td>
<td>69</td>
<td>71</td>
<td>73</td>
</tr>
<tr>
<td>BB</td>
<td>115</td>
<td>123</td>
<td>131</td>
<td>137</td>
<td>144</td>
<td>149</td>
<td>154</td>
<td>159</td>
<td>163</td>
<td>167</td>
</tr>
<tr>
<td>B</td>
<td>200</td>
<td>220</td>
<td>239</td>
<td>255</td>
<td>271</td>
<td>285</td>
<td>297</td>
<td>309</td>
<td>320</td>
<td>330</td>
</tr>
<tr>
<td>CCC/C</td>
<td>322</td>
<td>383</td>
<td>440</td>
<td>493</td>
<td>542</td>
<td>588</td>
<td>631</td>
<td>671</td>
<td>709</td>
<td>744</td>
</tr>
</tbody>
</table>

**Table 21:** Rbs sensitivity with respect to coupon changes

---

198 Own calculations (Model.xls / sheet / RBS financial_sensitivity) on the basis of Rappoport, 2001b, p. 7 as cited in Schaffner, 2010, p. 43.
Figure 17: Rbs sensitivity with respect to coupon changes

<table>
<thead>
<tr>
<th>Rock-bottom spreads financial institutions</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AAA</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>AA</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>12</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>A</td>
<td>17</td>
<td>19</td>
<td>20</td>
<td>21</td>
<td>22</td>
<td>23</td>
<td>24</td>
<td>25</td>
<td>26</td>
</tr>
<tr>
<td>BB</td>
<td>55</td>
<td>57</td>
<td>59</td>
<td>61</td>
<td>62</td>
<td>64</td>
<td>65</td>
<td>67</td>
<td>68</td>
</tr>
<tr>
<td>BB</td>
<td>117</td>
<td>129</td>
<td>137</td>
<td>143</td>
<td>148</td>
<td>152</td>
<td>154</td>
<td>156</td>
<td>158</td>
</tr>
<tr>
<td>B</td>
<td>331</td>
<td>338</td>
<td>339</td>
<td>337</td>
<td>333</td>
<td>328</td>
<td>323</td>
<td>318</td>
<td>314</td>
</tr>
<tr>
<td>CCC/C</td>
<td>1557</td>
<td>1313</td>
<td>1137</td>
<td>1007</td>
<td>911</td>
<td>838</td>
<td>781</td>
<td>737</td>
<td>701</td>
</tr>
</tbody>
</table>

Table 22: Rbs financial institutions

<table>
<thead>
<tr>
<th>Rock-bottom spreads corporates</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AAA©</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>AA©</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>A©</td>
<td>16</td>
<td>17</td>
<td>19</td>
<td>20</td>
<td>22</td>
<td>23</td>
<td>25</td>
<td>26</td>
<td>28</td>
</tr>
<tr>
<td>BBB©</td>
<td>35</td>
<td>39</td>
<td>43</td>
<td>47</td>
<td>51</td>
<td>55</td>
<td>58</td>
<td>61</td>
<td>64</td>
</tr>
<tr>
<td>BB©</td>
<td>99</td>
<td>119</td>
<td>135</td>
<td>148</td>
<td>159</td>
<td>168</td>
<td>175</td>
<td>181</td>
<td>186</td>
</tr>
<tr>
<td>B©</td>
<td>410</td>
<td>444</td>
<td>460</td>
<td>465</td>
<td>466</td>
<td>461</td>
<td>456</td>
<td>450</td>
<td>444</td>
</tr>
<tr>
<td>CCC/C©</td>
<td>2631</td>
<td>2143</td>
<td>1800</td>
<td>1558</td>
<td>1384</td>
<td>1256</td>
<td>1160</td>
<td>1086</td>
<td>1028</td>
</tr>
</tbody>
</table>

Table 23: Rbs corporations

199 Own calculations (Model.xls / sheet / RBS financial institutions_basic) on the basis of Henriques et al., 2006, p. 35-36 with the respective migration matrix from S&P, 2012.

200 Own calculations (Model.xls / sheet / RBS corporates_basic) on the basis of Henriques et al., 2006, p. 35-36 with the respective migration matrix from S&P, 2012.
Appendix 3

<table>
<thead>
<tr>
<th>Qualifier</th>
<th>Adjustment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very strong</td>
<td>+ 2 notches</td>
</tr>
<tr>
<td>Strong</td>
<td>+ 1 notch</td>
</tr>
<tr>
<td>Adequate</td>
<td>0 notches</td>
</tr>
<tr>
<td>Moderate</td>
<td>-1 notch</td>
</tr>
<tr>
<td>Weak</td>
<td>-2 to -3 notches</td>
</tr>
<tr>
<td>Very weak</td>
<td>-5 notches</td>
</tr>
</tbody>
</table>

Table 24: Rating adjustment for the "business position"\textsuperscript{201}

<table>
<thead>
<tr>
<th>Qualifier</th>
<th>Adjustment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very strong</td>
<td>+ 2 notches</td>
</tr>
<tr>
<td>Strong</td>
<td>+ 1 notch</td>
</tr>
<tr>
<td>Adequate</td>
<td>0 notches</td>
</tr>
<tr>
<td>Moderate</td>
<td>-1 notch</td>
</tr>
<tr>
<td>Weak</td>
<td>-2 notches</td>
</tr>
<tr>
<td>Very weak</td>
<td>-5 notches</td>
</tr>
</tbody>
</table>

Table 25: Rating adjustments for the "risk position"\textsuperscript{202}

\textsuperscript{202} On the basis of S&P, p. 13.
<table>
<thead>
<tr>
<th>Descriptor</th>
<th>Strong</th>
<th>Adequate</th>
<th>Moderate</th>
<th>Weak</th>
<th>Very weak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above Average</td>
<td>+1</td>
<td>0</td>
<td>-1</td>
<td>-2</td>
<td>-5</td>
</tr>
<tr>
<td>Average</td>
<td>0</td>
<td>0</td>
<td>-1</td>
<td>-2</td>
<td>-5</td>
</tr>
<tr>
<td>Below average</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-2</td>
<td>-5</td>
</tr>
</tbody>
</table>

### Table 26: Rating adjustments for "liquidity & funding"\textsuperscript{203}

#### Appendix 4

\[
(1 + i_2)^{d_2} = (1 + i_1)^{d_1} (1 + i_{t_1,t_2})^{d_2 - d_1} \quad \Leftrightarrow \quad \left( \frac{1 + i_2}{1 + i_1} \right)^{\frac{1}{d_2 - d_1}} - 1 = i_{t_1,t_2}
\]

- \( i_{t_1,t_2} = \) forward rate from time \( t_1 \) to \( t_2 \)
- \( d_1 = \) time between 0 and \( t_1 \) in years
- \( i_1 = \) interest rate from 0 to time \( t_1 \)
- \( d_2 = \) time between 0 and \( t_2 \) in years
- \( i_2 = \) interest rate from 0 to time \( t_2 \)

5-year CHF mid market swap rate (from 22. March 2012) = 0.583 %

10-year CHF mid market swap rate (from 22. March 2012) = 1.188 %

\[
\Rightarrow \quad i_{5,5} = \left( \frac{1 + 0.01188}{1 + 0.00583} \right)^{\frac{1}{5}} - 1 = 1.796639\%
\]

5-year US Dollar mid market swap rate (from 22. February 2012) = 1.172 %

10-year US Dollar mid market swap rate (from 22. February 2012) = 2.109 %

\[
\Rightarrow \quad i_{5,5} = \left( \frac{1 + 0.02109}{1 + 0.01172} \right)^{\frac{1}{5}} - 1 = 3.054678\%
\]

## Appendix 5

### Rating transition Matrix (AAA-BBB+)

<table>
<thead>
<tr>
<th></th>
<th>AAA</th>
<th>AA+</th>
<th>AA</th>
<th>AA-</th>
<th>A+</th>
<th>A</th>
<th>A-</th>
<th>BBB+</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAA</td>
<td>91.16%</td>
<td>6.40%</td>
<td>1.28%</td>
<td>0.32%</td>
<td>0.11%</td>
<td>0.32%</td>
<td>0.11%</td>
<td>0.00%</td>
</tr>
<tr>
<td>AA+</td>
<td>2.21%</td>
<td>75.67%</td>
<td>15.97%</td>
<td>4.18%</td>
<td>0.98%</td>
<td>0.73%</td>
<td>0.25%</td>
<td>0.00%</td>
</tr>
<tr>
<td>AA</td>
<td>0.41%</td>
<td>1.85%</td>
<td>79.27%</td>
<td>11.98%</td>
<td>4.26%</td>
<td>1.45%</td>
<td>0.16%</td>
<td>0.48%</td>
</tr>
<tr>
<td>AA-</td>
<td>0.00%</td>
<td>0.05%</td>
<td>5.08%</td>
<td>79.66%</td>
<td>10.86%</td>
<td>3.38%</td>
<td>0.60%</td>
<td>0.32%</td>
</tr>
<tr>
<td>A+</td>
<td>0.00%</td>
<td>0.10%</td>
<td>0.42%</td>
<td>6.26%</td>
<td>80.63%</td>
<td>9.17%</td>
<td>2.12%</td>
<td>0.42%</td>
</tr>
<tr>
<td>A</td>
<td>0.00%</td>
<td>0.04%</td>
<td>0.16%</td>
<td>0.64%</td>
<td>7.25%</td>
<td>79.81%</td>
<td>8.24%</td>
<td>2.41%</td>
</tr>
<tr>
<td>A-</td>
<td>0.11%</td>
<td>0.00%</td>
<td>0.16%</td>
<td>0.41%</td>
<td>0.72%</td>
<td>10.57%</td>
<td>76.80%</td>
<td>6.26%</td>
</tr>
<tr>
<td>BBB+</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.13%</td>
<td>0.39%</td>
<td>0.39%</td>
<td>1.15%</td>
<td>9.09%</td>
<td>77.53%</td>
</tr>
<tr>
<td>BBB</td>
<td>0.00%</td>
<td>0.06%</td>
<td>0.20%</td>
<td>0.13%</td>
<td>0.27%</td>
<td>0.40%</td>
<td>1.88%</td>
<td>9.99%</td>
</tr>
<tr>
<td>BBB-</td>
<td>0.00%</td>
<td>0.09%</td>
<td>0.00%</td>
<td>0.09%</td>
<td>0.09%</td>
<td>0.52%</td>
<td>0.25%</td>
<td>1.55%</td>
</tr>
<tr>
<td>BB+</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.32%</td>
<td>0.16%</td>
<td>0.16%</td>
<td>0.00%</td>
<td>0.80%</td>
</tr>
<tr>
<td>BB</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.17%</td>
<td>0.00%</td>
<td>0.17%</td>
<td>0.00%</td>
<td>0.50%</td>
</tr>
<tr>
<td>BB-</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>B+</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>B</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>B-</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>CCC/C</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

**Table 27:** 18-state Rating Transition Matrix (AAA – BBB+)

### Rating transition Matrix (BBB-D)

<table>
<thead>
<tr>
<th></th>
<th>BBB</th>
<th>BBB-</th>
<th>BB+</th>
<th>BB</th>
<th>BB-</th>
<th>B+</th>
<th>B-</th>
<th>CCC/C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAA</td>
<td>0.21%</td>
<td>0.00%</td>
<td>0.11%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>AA+</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>AA</td>
<td>0.00%</td>
<td>0.16%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>AA-</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>A+</td>
<td>0.42%</td>
<td>0.14%</td>
<td>0.04%</td>
<td>0.14%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.10%</td>
</tr>
<tr>
<td>A</td>
<td>0.95%</td>
<td>0.20%</td>
<td>0.04%</td>
<td>0.04%</td>
<td>0.04%</td>
<td>0.04%</td>
<td>0.04%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>A-</td>
<td>2.61%</td>
<td>1.38%</td>
<td>0.36%</td>
<td>0.16%</td>
<td>0.20%</td>
<td>0.05%</td>
<td>0.05%</td>
<td>0.05%</td>
<td>0.11%</td>
</tr>
<tr>
<td>BBB+</td>
<td>7.44%</td>
<td>2.23%</td>
<td>0.50%</td>
<td>0.19%</td>
<td>0.06%</td>
<td>0.13%</td>
<td>0.19%</td>
<td>0.19%</td>
<td>0.32%</td>
</tr>
<tr>
<td>BBB</td>
<td>77.35%</td>
<td>5.23%</td>
<td>2.01%</td>
<td>0.87%</td>
<td>0.60%</td>
<td>0.33%</td>
<td>0.13%</td>
<td>0.06%</td>
<td>0.00%</td>
</tr>
<tr>
<td>BBB-</td>
<td>11.37%</td>
<td>76.31%</td>
<td>4.48%</td>
<td>2.33%</td>
<td>0.95%</td>
<td>0.95%</td>
<td>0.09%</td>
<td>0.25%</td>
<td>0.00%</td>
</tr>
<tr>
<td>BB+</td>
<td>2.70%</td>
<td>14.49%</td>
<td>69.42%</td>
<td>5.73%</td>
<td>1.91%</td>
<td>0.96%</td>
<td>0.80%</td>
<td>0.16%</td>
<td>1.11%</td>
</tr>
<tr>
<td>BB</td>
<td>0.83%</td>
<td>2.64%</td>
<td>12.52%</td>
<td>72.63%</td>
<td>4.61%</td>
<td>1.64%</td>
<td>1.48%</td>
<td>0.50%</td>
<td>1.48%</td>
</tr>
<tr>
<td>BB-</td>
<td>0.46%</td>
<td>0.62%</td>
<td>3.38%</td>
<td>9.54%</td>
<td>71.39%</td>
<td>5.85%</td>
<td>4.62%</td>
<td>1.85%</td>
<td>0.77%</td>
</tr>
<tr>
<td>B+</td>
<td>0.00%</td>
<td>0.56%</td>
<td>1.11%</td>
<td>2.78%</td>
<td>14.60%</td>
<td>69.31%</td>
<td>4.44%</td>
<td>3.69%</td>
<td>1.11%</td>
</tr>
<tr>
<td>B</td>
<td>0.24%</td>
<td>0.24%</td>
<td>0.49%</td>
<td>0.73%</td>
<td>3.16%</td>
<td>16.55%</td>
<td>63.26%</td>
<td>4.86%</td>
<td>4.86%</td>
</tr>
<tr>
<td>B-</td>
<td>0.32%</td>
<td>0.00%</td>
<td>0.32%</td>
<td>0.32%</td>
<td>0.95%</td>
<td>2.55%</td>
<td>18.78%</td>
<td>66.23%</td>
<td>5.42%</td>
</tr>
<tr>
<td>CCC/C</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.53%</td>
<td>0.53%</td>
<td>1.06%</td>
<td>2.64%</td>
<td>2.12%</td>
<td>16.94%</td>
<td>56.61%</td>
</tr>
</tbody>
</table>

**Table 28:** 18-state Rating Transition Matrix (BBB+ – D)

---


Declaration of Authorship

I hereby declare
- that I have written this thesis without any help from others and without the use of documents and aids other than those stated above,
- that I have mentioned all used sources and that I have cited them correctly according to established academic citation rules.

______________________________

Sina Öfinger