How do CoCo bonds impact a bank's shareholder wealth?

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ABSTRACT

The 2008 crisis highlighted the fragility of the banking system. To address this deficiency, the Basel committee agreed on the Basel III Accord to strengthen banks' capital requirements. However, raising additional common equity funds is costly. Faced with this problem, banks and regulators wonder whether capital can be raised in other ways which are less expansive. To this end, Contingent Convertible (CoCo) bonds have been designed to absorb banks' losses instead of equity in times of crisis. Might CoCo securities be an effective prevention and/or rescue solution? This article examines the impact of Debt-to-Equity CoCo bonds on a bank's capital structure. Leverage ratios based on risk-weighted-assets are used for the first time as equity conversion triggers instead of traditional capital ratios based on risk-weighted-assets. We find that CoCo bonds generally increase shareholders' wealth by reducing their bankruptcy risk, except when the dilution effect offsets this positive effect. In this sense, by boosting banks' capacity to absorb losses while giving regulators more time to find a rescue solution, CoCo bonds reinforce the financial stability. We also highlight the importance of defining properly different variables and/or parameters while designing CoCo bonds. With right choices, CoCo bonds can better fulfil their function as "going-concern" capital, while banks' shareholders can maximize their wealth and reconcile their financial interests with banking regulators' the risk prevention objectives.

JEL Classifications: G21, G13, G19

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1. Introduction

The 2008 worldwide economic and financial crisis highlighted the fragility of the banking system. International financial groups recorded heavy losses due to their investments in mortgage-backed securities, asset-backed securities, collateralized-debt obligations and their commitments in credit-default swaps. These losses were so huge that banks no longer possessed enough capital to operate normally as financial intermediaries, forcing American and European governments to bail them out.

In response to this deficiency, the Basel Committee agreed upon the third version of the Basel Accord to strengthen banks' capital, particularly their "Tier One Capital." "Tier One Capital" comprises "Core Tier One" (or CET1 including common equity and retained earnings) and "Additional Tier One" (or AT1 including "non-redeemable non-cumulative preferred equity" and some innovative instruments developed in recent years) capital. As indicated in the *Financial Times* of September 13, 2010, "*Basel III sets a new capital ratio of 4.5% for the core tier one, more than double its current level of 2%, plus a new buffer of an additional 2.5%. In this way, the rule sets a floor of 7% (i.e., the sum of 4.5% and 2.5%) for the common equity tier one, below which banks will face restrictions on paying dividends and discretionary bonuses*". To comply with Basel III to be implemented in 2019, banks will be required to raise hundreds of billions of additional funds in common equity.

Faced with such a requirement, banks and regulators are considering whether capital might be raised in other less costly ways. "Contingent Convertible (CoCo)" bonds are one of these possibilities (see Flannery (2005), Avdjiev *et al.* (2013), De Spiegeleer *et al.* (2014)). CoCo bonds are debt securities that can be converted into equity like convertible bonds. However, they differ from traditional convertible bonds in several respects. First, their conversion is automatic, as it is triggered by a specific event (for example when a given variable reaches a certain level), while the conversion of a convertible bond is decided by its holder.

Secondly, CoCo bondholders are asked to "get through difficult times" with shareholders, while convertible bondholders are invited to "share happy hours" with shareholders. Finally, CoCo bonds provide higher interest coupon rates than classic bonds because of their higher-risk profile, while convertible bonds provide lower rates due to the conversion option held by bondholders. Lloyds issued the first CoCo bonds in 2009. Equity conversion should be triggered when the bank's CET1 capital to risk-weighted assets ratio falls to 5%. Another example is the CoCo bond issued by Rabobank in 2011. The equity conversion is triggered when the bank's CET 1 ratio reaches 8%.

Originally, the name "CoCo bonds" was confined to "Debt-To-Equity" bonds which are converted into equity in case of a trigger event. Later, this term has been extended to other contingent bonds that regulators recognize as "AT1" or "Tier 2" capital. These contingent bonds include mainly "Write-Down" and "Write-Off" CoCo bonds (see Bleich (2014)). Unlike Debt-To-Equity bonds, Write-Down bonds are not converted into equity in case trigger event; instead, their principal and/or coupon are reduced to a certain percentage. Rabobank issued this kind of bond in 2010: its principal is reduced by 75% of its nominal level when the CET1 ratio falls to 7%, which means that only 25% of the principal will be repaid. All things being equal otherwise, Write-Down CoCo bonds are riskier than Debt-To-Equity bonds, as their holders lose definitively the reduced part of the principal and/or coupon, while holders of Debt-To-Equity bonds may still have the possibility to get paid as shareholders if the bank recovers. Regarding Write-Off bonds, they can be considered as a particular case of Write-Down bonds, as their principal and/or coupon are reduced to zero in case of a trigger event.

Between late 2009 and early 2015, more than 200 CoCo bonds were issued for regulatory purposes. Most them were issued by European banks, while others were issued made by banks in emerging countries such as BRICS (see Barclays (2014), Schmid (2014), Glover and Bearsworth (2016)). From 2013 to 2015, European banks had issued more than $100 billion of CoCo bonds considered as AT1 or T2 capital. So far, CoCo bonds have been a great success with investors with a substantial oversubscription (see Bjorn-Nordal and Stefano (2014)).

The wide interest in CoCo bonds could be explained by investors' desire for higher remuneration in a context of historically low interest rates (i.e., a 0.25% rate for FED fund in the USA until late 2015, and a 0% for ECB rate in the Eurozone since March 2016). The success of CoCo bonds could also be explained by their economic purpose, that of boosting a bank's capacity to absorb losses. In case of a trigger event, the coupon and/or the nominal principal of the CoCo debts are cancelled through an equity conversion or a simple principal and/or coupon cancellation. In both cases, the bank's debt is reduced and its solvency is improved.

To note that the most interesting characteristic of CoCo bonds is their "bail-in" feature, which means that a "rescue" actually takes place before the bankruptcy process is triggered. For this reason, CoCo bonds are considered as "going-concern" capital in contrast with "gone-concern" capital, which steps in only after the bankruptcy process is triggered. An example of gone-concern capital is subordinated debts. During the 2008 crisis, subordinated debtholders, supposed to share risks with shareholders in the event of distress, remained intact because banks had already been "bailed out" by governments before they were asked to do anything. Such a situation could have been avoided with CoCo bonds: in cases of huge losses, CoCo bonds would have been transformed into equity or just cancelled, and CoCo bondholders would have been involved in "bailing-in" banks before taxpayers were called up to "bail them out."

This is effectively what was observed in the financial markets in early 2016 with Deutsch Bank's CoCo bonds. In late January, Deutsche Bank reported a fourth-quarter net loss of €2.1 billion and a full-year net loss of €6.8 billion due to litigation costs and restructuring charges. Following this warning, the German bank's stock price plummeted. As CoCo bondholders worried that a coupon payment might be missed, they began to sell off mass quantities of their securities, reducing the CoCo bond's price to its lowest ever level. As reported in the *Financial Times* on February 5, 2016, "*A €1.75bn Deutsche CoCo with a 6% coupon is now trading at just over 80 cents on the euro, its lowest ever level. Another bond with a 7.5% coupon is at 87.1 cents on the dollar. The bonds have lost 13% and 10% of their value respectively since the start of January*." The price decline also involved CoCo bonds issued by other European banks (including Santander and UniCredit), because the banking sector as a whole was under pressure (see Williams-Grut (2014)). This phenomenon provides a good example of how CoCo bonds can help to restore banks' capital, and how their holders are obliged to deal with risks in times of stress even though the trigger event did not happen to Deutsche Bank's CoCo bonds in the end. As indicated in *Financial Times* on September 16, 2016, "*for the bank to miss a coupon payment on its AT1s it would need to undergo a hit to tier one capital of €7.5bn. Taking into account pre-tax profit and existing litigation reserves, ... this would correspond to a fine of $14bn. To trigger a writedown on the AT1 securities – an unprecedented event for bonds sold by major banks over recent years – would require a capital hit of €16bn.*"

Can CoCo bonds be a preventative instrument and/or a rescue solution in times of crisis? Opinions are divided. Many are sceptical, considering that CoCo bonds only delay defaults that should happen, while accumulated defaults would further weaken the financial system (see Hart and Zingales (2010)). Some believe that, even though CoCo bonds provide loss-absorbing capital, they do not generate "additional cash," and so cannot resolve liquidity problems (Culp (2009)); others think that CoCo bonds can have a negative effect on banks' creditworthiness and firm value (see Schmidt and Azami (2015)). Some even consider CoCo bonds as "death spiral bonds" because they may create "perverse incentives" when banks enter into a delicate area relative to the trigger event (Berg and Kaserer (2015)).

On the other hand, CoCo bonds have also received a lot of support, and many think that they could be an effective solution to crisis. First, by strengthening individual banks by boosting their capacity to absorb losses, CoCo bonds give regulators more time to find a rescue solution for the financial system as a whole. Second, CoCo bonds can help banks to reduce their moral hazard risk-taking incentive (see Acharya and Richardson (2009), Flannery (2009a), Pennacchi (2010), Von Furstenberg (2011), Hilscher and Raviv (2012), Pennacchi *et al.* (2014)). Finally, they can increase firm value and reduce the chance of costly bankruptcy or bailout (see Albul *et al.* (2016)).

CoCo bonds have attracted substantial interest from academics over the last few years. Existing academic research can be divided into two groups. The first investigates CoCo bond design by focusing on capital structure optimization (see De Martino *et al.* (2010), McDonald (2010), Squam Lake Group (2010), Hilscher and Raviv (2012), Barucci and Del Viva (2012) (2013)). The second deals with valuation aspects using mathematical models (see Lai and Van Order (2011), De Spiegeleer and Schoutens (2012), Wilkens and Bethke (2014), Brigo *et al.* (2015)). For a review of the literature on CoCo bonds, see Calomiris and Herring (2013).

This paper examines the impact of Debt-To-Equity CoCo bonds on banks' capital structure. More precisely, it analyzes whether CoCo bonds increase or reduce shareholders' wealth, and how should banks choose the different parameters to maximize their shareholders' wealth. The rest of the paper is organized as follows. Section 2 presents the capital structure of the bank and shows how to deal with the main variables of a CoCo bond issue (including how to choose the trigger indicator and how to define the trigger threshold and the conversion ratio). Section 3 specifies the mathematical model, derives the closed-form formula of shareholder wealth, and presents some numerical analysis. Section 4 summarizes the main results obtained in the paper, discusses their potential implications, and outlines some perspectives for future research.

2. Capital structure and CoCo bond design

2.1. Bank capital structure

As in the model of Black and Scholes (1973) and Merton (1973), we suppose that the bank is financed with equity S and a single zero-coupon bond with B as face value and T as maturity date. We also suppose that the bank makes no payouts to its shareholders and does not raise new equity before the bond matures. Unlike the Black-Scholes-Merton model, the bond is not wholly traditional. It is broken down into two parts: the first is a Debt-To-Equity CoCo zero-coupon bond with αB as face value, while the second is a classic zero-coupon bond with (1–α)B as face value, where α is a coefficient between 0 and 100% (see Figure 1).

(Insert Figure 1 here)

As the bank's assets and liabilities should be equal at any time t, we have: $S_t + \alpha B_t^{cc} + (1-\alpha)B_t = V_t$, where S_t represents the value of the equity, B_t^{cc} and B_t represent the values of the CoCo bond and the traditional bond respectively, with $B_T^{cc} = B_T = B$, and V_t represents the sum of the bank's assets. When α = 0, the model is the same as the Black-Scholes-Merton model without any CoCo bonds. When α = 1, the whole part of the debt is a CoCo bond.

The CoCo mechanism works in the following way: if the trigger is not activated throughout the period *[0, T]*, the CoCo bond will behave like a traditional zero-coupon; otherwise, if the trigger is activated at time *t** with *t** ∈ *[0, T]*, the CoCo bond will be converted into equity with a predetermined conversion ratio *β*, which means that the CoCo bond with a face value *αB* will be transformed into *αβ* units of equity.

Figure 2 illustrates how bank capital can be strengthened with the help of CoCo bonds. Figure 2(a) presents the capital structure of the bank. In Figure 2(b), the bank's assets depreciate and reach the trigger level at time *t**. In Figure 2(c), the CoCo bond is converted into equity, which reduces the bank's debt by the sum of αB_{t*}^{cc} (whose face value is αB) while boosting its equity by the same amount, where B_{t*}^{cc} is the value at time $t*$ of a CoCo bond with face value B at time T. As a result, the equity is increased from S_{t*} to $(S_{t*} + \alpha B_{t*}^{cc})$. The higher the value of α, the greater the increase in equity and the more the bank's shareholders are protected against bankruptcy.

(Insert Figure 2 here)

2.2. Choosing the trigger indicator

The key variable to be defined in a Coco bond contract is the "trigger indicator," which determines how and when CoCo conversion takes place. In the literature, trigger events are usually based on three types of variables, namely decisions by a regulatory body, market data, and capital ratios.

First, conversion decision can be made by a regulatory body according to information it holds on the bank. This approach has the advantage of offering each bank a tailor-made solution without imposing the same requirements on all banks. However, the 2008 crisis taught us that regulators may not react quickly enough in times of distress, while the very purpose of CoCo bonds is to provide a prompt answer to banks in difficulty. For this reason, regulators' decisions do not seem the most appropriate to be chosen as trigger indicators.

Second, conversion decision can also be based on market data such as the bank's stock price or its CDS spreads. For example, equity conversion can be triggered when the stock price falls to a certain low or when one of its CDS spreads climbs to a certain high[1], because both of these events indicate that the bank has an increasing solvency risk. Even though market data are more objective than other indicators thanks to their transparency, they may pose other problems because of inherent flaws in market activity. In fact, banks may suffer from "unjustified" equity conversion due to a "market caprice" related to market manipulation or

[1] Following the "profit warning" by Deutsche Bank in late January 2016, the German bank's stock price fell, and the five-year CDS spread, which offers protection against default on Deutsche Bank's senior debt, spiked to three-and-a-half-year highs a few days later.

market over-reaction (cf. Flannery (2009b), Flannery and Perotti (2011)). As a result, market-based variables alone do not seem to be the most appropriate trigger indicator either.

Finally, conversion decision can be based on banks' capital ratios including "traditional capital ratios" (based on CET1, Tier 1, or Tier 2), "leverage ratios", and "liquidity ratios" (such as "liquidity coverage ratio" and "net stable funding ratio", see Bishop *et al.* (2010)). This approach seems to be the most appropriate, as it is directly linked to the Basel capital requirements (see Goldman Sachs Global Markets Institute (2011)). So far, the ratio of CET1 to risk-weighted-assets is the most used in existing CoCo bond issues (see Table 1).

(Insert Table 1 here)

Of the various capital ratios, we have decided to use "leverage ratios," which are reintroduced in Basel III after having been abandoned in Basel II. A "leverage ratio" is the ratio of a capital to the sum of the bank's assets. The Basel III Accord requires banks to maintain at least 3% of the sum of their assets as tier one capital in 2018. This means that banks will not be allowed to invest more than 33.3 times their tier one capital, regardless of the nature of the investments. In July 2013, the US Federal Reserve Bank announced that, for the eight largest American banks, the leverage ratio based on tier one capital should be higher than 6%, double the minimum required in Basel III. In the United-Kingdom, the Bank of England recommends a leverage ratio of between 4% and 7%.

The key difference between leverage ratios and traditional capital ratios lies in how the sum of the assets is calculated. In leverage ratios, assets are simply aggregated without any weighting system, which means that their sum is not weighted by risk. However, in traditional capital ratios, assets are first multiplied by their "risk coefficient[2]" before being added up, which means that their sum is weighted by the risk of each asset. Therefore, leverage ratios are

[2] The risk coefficient of an asset means "the percentage of loss which may result from the asset". It is 100% for "high-risk" assets (such as corporate loans), 50% for "low-risk" assets (such as mortgage assets), and 0% for "risk-free" assets (such as cash or triple-A-rated assets).

based on "Non-Risk-Weighted Assets" (NRWA), while traditional capital ratios are based on "Risk-Weighted Assets" (RWA).

We chose leverage ratios as CoCo conversion trigger criteria rather than traditional capital ratios because they may be more effective in warning of early-stage risk. On the eve of the 2008 crisis, most investment banks (including Bear Sterns, Lehman Brothers, Wachovia, and Merrill Lynch) were heavily indebted, while their traditional capital ratios were "more than correct" with regard to Basel II and even Basel III requirements. This means that traditional capital ratios failed to warn banks and regulators of a risky situation, even though it was rather obvious. The failure of traditional capital ratios was mainly due to undervaluation of their denominator – the RWA. In fact, to maximize their capital ratios or to minimise the amount of their required capital, banks tried deliberately to minimize their RWA by undervaluing the risk weight allocated to each asset[3]. Based on NRWA, leverage ratios can avoid this problem. As indicated in the *Financial Times* on July 11, 2014, "*Global regulators have been placing increasing weight on leverage ratios because they mistrust traditional capital measures in which banks adjust their exposures according to the risks they are running*."

Of course, like all measures, NRWA-based ratios are not flawless either. For example, for the same amount of capital required, leverage ratios may lead banks to allocate more investment to high-risk assets because the risk level is no longer weighted in the capital requirement. Nevertheless, combined with other prudential policy tools, leverage ratios offer useful alternative devices to reduce excessive leverage in individual banks and so in the whole financial system. In this respect, they can contribute to improving the financial stability.

[3] The lack of accuracy and consistency in computing RWA is confirmed by a study released by the Basel Committee on Banking Supervision in July 2013, entitled "*Regulatory consistency assessment program: analysis of risk-weighted assets for credit risk in the banking book*." This report highlighted "considerable variation" in the way banks assess the amount of risk in the securities on their balance sheets.

2.3. Defining the trigger level

Setting the trigger threshold is a challenge. A trigger should be neither too low nor too high. Not too low, so as to trigger the rescue as soon as the bank shows a sign of weakness, but nor too high either, to avoid unnecessary equity conversion due to the volatility inherent in business cycles and financial markets. Then, how can we judge whether a trigger level is appropriate?

One useful reference, but not the only one, is the minimum level required by banking regulators. Setting conversion triggers at the level of a regulatory ratio has at least two advantages. First, it is practical. In the event that a regulatory minimum is reached, CoCo conversion will be triggered, capital will be restored with new equity, leverage ratios will be in line again with regulatory requirements, and other capital ratios will also be strengthened. This allows banks to avoid being downgraded by the rating agencies and having to pay higher interest rates. Second, regulatory ratios should normally be well founded, or at the very least, should be less arbitrary than other ratios, because they are established by regulatory authorities, which are considered as experts in the area of banking risk prevention.

How does this work in practice? So far, no CoCo bond conversion is based on leverage ratios. To get an idea of how triggers are positioned relative to regulatory ratios, we can examine CoCo bonds whose conversion is based on traditional capital ratios. As shown in Table 1, trigger levels, based on the ratio of CET1 to RWA and varying from 5% to 7%, are all higher than 4.5%, the regulatory minimum of this capital ratio.

Here, we suppose that the trigger threshold l* is set at 3%, the minimum level of the Tier 1 leverage ratio required by Basel III. In our model, the Tier 1 leverage ratio is equal to (S_t/V_t), where S_t is the value of the equity at time t and V_t the sum of the bank's assets. If we represent the value of the CoCo bond at time t by αB_t^{cc} and the value of the traditional bond by $(1-\alpha)B_t$, the trigger event can be defined as follows:

$$\frac{S_t}{V_t} \leq l^* \Leftrightarrow S_t \leq l^* V_t$$

$$\Leftrightarrow V_t - \alpha B_t^{cc} - (1-\alpha) B_t \leq l^* V_t$$

$$\Leftrightarrow (1-l^*) V_t \leq \alpha B_t^{cc} + (1-\alpha) B_t$$

$$\Leftrightarrow V_t \leq \frac{\alpha B_t^{cc} + (1-\alpha) B_t}{1-l^*} = L^*$$

This means that the trigger event based on the leverage ratio (at level l*) is henceforth transformed on a trigger event based on the value of the bank's assets (at level L*). The fact that L* evolves with time t is embarrassing for us to carry on our analysis. As a result, we need to choose a trigger level, L, that does not depend on time t. Normally, as it is the case in practice, this constant trigger L should be higher than L*, so that equity conversion can take place before the regulatory minimum is reached.

Unlike risk-free bonds, CoCo bonds and traditional bonds are exposed to credit risk. So, other things being the same otherwise, they deserve higher yields to maturity than risk-free bonds, or they are worth less. Similarly, as CoCo bonds are exposed to higher risks than traditional bonds[4], they deserve the highest yields to maturity, or they are worth the least among the three types of bonds.

Let's note r as the risk-free interest-rate, r_B and r_B^{cc} the respective yields to maturity of the traditional bond and the CoCo bond, we have: $r_B^{cc} \geq r_B \geq r$, and $B_0^{cc} = B \times e^{-r_B^{cc} T} \leq B_0 = B \times e^{-r_B T} \leq Be^{-rT}$, where Be^{-rT} is the present value of the risk-free bond.

From the last inequality, we have:

$$L^* = \frac{\alpha B_t^{cc} + (1-\alpha) B_t}{1-l^*} \leq \frac{Be^{-rT}}{1-l^*} = L$$

The constant trigger L can be defined as:

[4] In 2013, Crédit Agricole issued the first CoCo bond in France with a value of one billion US dollars. These CoCo bonds were rated "BBB-" by Standard and Poor's (which is three notches below that of the bank's traditional debts) and by Fitch (which is four notches below its conventional debts). For the higher risk profile of CoCo bonds, see also Berg and Kaserer (2015).

$$L = \frac{Be^{-rT}}{1-l^*} \quad (1)$$

With $B = 90$, $l^* = 3\%$, r = 2%, T = 3 years, we have $L = 87.4$. From now on, this constant trigger L is chosen as one of our "standard parameters".

2.4. Defining the conversion ratio

The conversion ratio β is defined as the amount of stock that CoCo bondholders will obtain in case of equity conversion. More precisely, the CoCo bond with a face value of αB will be transformed into $\alpha\beta$ units of equity whose value at t^* is $\alpha\beta S_{t^*}$, where t^* is the triggering time. In principle, the conversion ratio should be defined so that CoCo bondholders' wealth remains the same before (as bondholders) and after (as new shareholders) the conversion. This leads to: $\alpha B_{t*}^{cc} = \alpha\beta S_{t*}$, or $\beta = B_{t*}^{cc}/S_{t*}$, where B_{t*}^{cc} represents the value at time t* of the CoCo bond and S_{t^*} the value of the equity. As the triggering time t* is unknown at time 0, neither B_{t*}^{cc} nor S_{t*} can be known in advance. Thus, β cannot be computed from [$\alpha B_{t*}^{cc} = \alpha\beta S_{t*}$].

So, we need to find another way to define β when designing CoCo contract. One possibility is to assume that the equation [$\alpha B_{t*}^{cc} = \alpha\beta S_{t*}$] holds at time t* = 0. This means that if CoCo conversion is triggered at time 0, CoCo bondholders' wealth will be the same before and after the conversion. From [$\alpha B_0^{cc} = \alpha\beta S_0$], we have:

$$\beta = \frac{B_0^{cc}}{S_0} = \frac{B_0^{cc}}{V_0 - \alpha B_0^{cc} - (1-\alpha)B_0} \quad (2)$$

With V_0 = 100, B = 90, r = 2%, $r_B = 5\%$, $r_B^{cc} = 7\%$, T = 3 years, and $\alpha = 0.3$, we get: $B_0^{cc} = 73.0$, $B_0 = 77.5$, $S_0 = V_0 - \alpha B_0^{cc} - (1-\alpha)B_0 = 23.9$, and β ≅ 3. Henceforth, β = 3 is chosen as one of our "standard parameters".

In case of CoCo conversion at time t*, shareholder wealth passes from S_{t*}^{bef} to S_{t*}^{aft}, with $S_{t*}^{aft} = \frac{S_{t*}^{bef} + \alpha B_{t*}^{cc}}{1+\alpha\beta}$. As we can see, shareholder wealth decreases with the conversion coefficient β. For this reason, β can be considered as a "dilution factor" for the hank's shareholders in terms of capital control and profit sharing.

3. Pricing model and numerical analysis

As in the model of Black-Scholes-Merton, the sum of the bank's assets is assumed to follow a Geometric Brownian Motion. In the neutral risk probability world, its movement can be written as:

$$\frac{dV_t}{V_t} = r\,dt + \sigma\,dW_t \tag{3}$$

Where r is the constant risk-free interest rate, σ is the standard-deviation of the instantaneous return rate of $(V_t)_t$, and W_t is the standard Wiener process under the risk-neutral probability. As in Chesney and Gibson-Asner (1999), we assume that the volatility σ is determined by the investment policy decided by the bank's shareholders. High-risk investments lead to high volatility, while low-risk investments lead to low volatility.

3.1. Shareholder wealth

The payoff at time T of the equity can be written as follows:

$$S_T = max\{0, V_T - B\}1_{m_T > L} + \frac{1}{1+\alpha\beta} max\{0, V_T - (1-\alpha)B\}1_{m_T \leq L} \tag{4}$$

Where m_T represents the minimum level attained by $(V_t)_t$ from *0* to *T*, and $1_{Condition}$ is an indicator function, with $1_{Condition} = \begin{cases} 1 \text{ if condition met} \\ 0 \text{ if not} \end{cases}$.

The first component of the right-hand side of Equation (4) can be considered as the payoff from a down-and-out call option, with *V* as underlying-asset price, *B* as strike-price, and *L* as barrier. The second component can be considered as $1/(1+\alpha\beta)$ unit of the payoff from a down-and-in call option, with *V* as underlying-asset price, $(1-\alpha)B$ as strike-price, and *L* as barrier. When $\alpha = 0$, the bank's capital structure comprises equity and a traditional bond, without any CoCo bonds. In this case, $S_T = max\{0, V_T - B\}$, and the equity is similar to a plain-vanilla call option as in the Black-Scholes-Merton model. On the other hand, when $\alpha = 1$, the bond is entirely CoCo bond.

To value the equity at time 0 from Equation (4), the approach is similar to the valuation of barrier options. When a barrier option is priced, two cases need to be distinguished: either the barrier is lower than the strike-price, or it is higher. The general valuation formulae are presented as follows, with three positioning scenarios (detailed developments to obtain these formulae are available from the author).

1) **Case 1: $\boldsymbol{L \geq B > (1-\propto)B}$**

In the first scenario, conversion trigger is higher than the face value of the whole part of the bank's debt. This scenario is the most cautious, because equity conversion takes place even when the bank is capable of repaying all its debt. If the trigger is touched before the maturity date, all debt will be converted into equity and there will be no bankruptcy risk for the bank henceforth; otherwise, at the maturity date, the value of the bank's assets will be higher than the trigger (that is higher than the face value of the whole debt), which means that the bank will be able to repay its debt. Shareholder wealth at time t = 0 can be written as:

$$S_0 = V_0 N(x) - Be^{-rT} N\left(x - \sigma\sqrt{T}\right) - \left[V_0 \left(\frac{L}{V_0}\right)^{2a+2} N(y) - Be^{-rT}\left(\frac{L}{V_0}\right)^{2a} N\left(y - \sigma\sqrt{T}\right)\right]$$

$$+\frac{1}{1+\alpha\beta}\left\{\left[V_0 N(z) - (1-\alpha)Be^{-rT} N\left(z - \sigma\sqrt{T}\right)\right]\right.$$

$$- \left[V_0 N(x) - (1-\alpha)Be^{-rT} N\left(x - \sigma\sqrt{T}\right)\right]$$

$$\left.+\left[V_0 \left(\frac{L}{V_0}\right)^{2a+2} N(y) - (1-\alpha)Be^{-rT}\left(\frac{L}{V_0}\right)^{2a} N\left(y - \sigma\sqrt{T}\right)\right]\right\} \qquad (5a)$$

With $x = \frac{ln\left(\frac{V_0}{L}\right)+(\mu+\sigma^2)T}{\sigma\sqrt{T}}$ $\quad y = \frac{ln\left(\frac{L}{V_0}\right)+(\mu+\sigma^2)T}{\sigma\sqrt{T}}$ $\quad z = \frac{ln\left(\frac{V_0}{(1-\alpha)B}\right)+(\mu+\sigma^2)T}{\sigma\sqrt{T}}$

$\mu = r - \frac{\sigma^2}{2}$ $\quad a = \frac{\mu}{\sigma^2}$

2) **Case 2: $\boldsymbol{B \geq L \geq (1-\propto)B}$**

In the second scenario, the trigger is lower than the face value of the whole debt, but is higher than the face value of the traditional debt. It is the case of our "standard parameter set" with B = 90 > L = 87.4 > [(1–α)×B] = 63. Shareholder wealth at time t = 0 can be written as:

$$S_0 = V_0 N(x^*) - Be^{-rT} N\left(x^* - \sigma\sqrt{T}\right) - \left[V_0 \left(\frac{L}{V_0}\right)^{2a+2} N(y^*) - Be^{-rT}\left(\frac{L}{V_0}\right)^{2a} N\left(y^* - \sigma\sqrt{T}\right)\right]$$

$$+ \frac{1}{1+\alpha\beta}\{\left[V_0 N(z) - (1-\alpha)Be^{-rT} N\left(z - \sigma\sqrt{T}\right)\right]$$

$$- \left[V_0 N(x) - (1-\alpha)Be^{-rT} N\left(x - \sigma\sqrt{T}\right)\right]$$

$$+ \left[V_0 \left(\frac{L}{V_0}\right)^{2a+2} N(y) - (1-\alpha)Be^{-rT}\left(\frac{L}{V_0}\right)^{2a} N\left(y - \sigma\sqrt{T}\right)\right]\} \qquad (5b)$$

With $x^* = \frac{ln\left(\frac{V_0}{B}\right) + (\mu + \sigma^2)T}{\sigma\sqrt{T}}$ $y^* = \frac{ln\left(\frac{L^2}{B \times V_0}\right) + (\mu + \sigma^2)T}{\sigma\sqrt{T}}$

3) Case 3: $B > (1{-}\propto)B \geq L$

In the last scenario, the trigger is even lower than the face value of the traditional debt. This scenario is the less cautious, because it means that equity conversion takes place only when the bank is not capable of repaying the face value of its traditional debt. Shareholder wealth at time t = 0 can be written as:

$$S_0 = V_0 N(x^*) - Be^{-rT} N\left(x^* - \sigma\sqrt{T}\right) - \left[V_0 \left(\frac{L}{V_0}\right)^{2a+2} N(y^*) - Be^{-rT}\left(\frac{L}{V_0}\right)^{2a} N\left(y^* - \sigma\sqrt{T}\right)\right]$$

$$+ \frac{1}{1+\alpha\beta}\left[V_0 \left(\frac{L}{V_0}\right)^{2a+2} N(z^*) - (1-\alpha)Be^{-rT}\left(\frac{L}{V_0}\right)^{2a} N\left(z^* - \sigma\sqrt{T}\right)\right] \qquad (5c)$$

Where $z^* = \frac{ln\left(\frac{L^2}{(1-\propto)B \times V_0}\right) + (\mu + \sigma^2)T}{\sigma\sqrt{T}}$

3.2. Numerical results and analysis

How does shareholder wealth vary with the different parameters, including the proportion of CoCo bond in the whole debt (α), the trigger threshold (L), and the conversion ratio (β)? When using CoCo bonds, how should banks' shareholders adapt their investment policy to the capital structure by choosing an appropriate level of volatility (σ)? Unless otherwise stated, the "standard parameters" used in this paper are as follows: $V_0 = 100$, $B = 90$, $r = 2\%$, $T = 3$ years, $\sigma = 20\%$, $\alpha = 0.3$, $\beta = 3$, $L = 87.4$.

1) Impact of β, the conversion ratio

Figure 3a shows that in the absence of CoCo bond (i.e., with $\alpha = 0$), shareholder wealth is insensitive to the conversion ratio β. On the other hand, in the presence of CoCo bond (i.e., with $\alpha > 0$), for a given α, shareholder wealth decreases with β. In fact, the higher β is, the higher the new shareholders' (or the current CoCo bondholders') capital share will be in case of CoCo conversion, and the lower the current shareholders' capital share will be, and so the lower their wealth. Furthermore, we note that the higher α is, the more quickly shareholder wealth decreases with β. This could be explained by a more significant dilution effect due to a higher CoCo bond proportion.

Figure 3b shows that the higher L is, the more sensitive shareholder wealth is relative to β. For example, when L = 50, shareholder wealth stays nearly at the same level when β varies; on the other hand, when L = 95, shareholder wealth decreases sensitively with β. This could be explained by the fact that the higher L is, the more likely CoCo conversion is, and so the greater the dilution effect on shareholder wealth.

(Insert Figures 3a and 3b here)

2) Impact of α, the proportion of CoCo bond in the whole debt

The impact of CoCo bond proportion, α, is quite complicated due to two opposing effects related to equity conversion. In fact, CoCo bond conversion has a positive impact on shareholders by protecting them against bankruptcy, but meanwhile, it has a negative impact due to its "dilution effect" in terms of capital control and profit sharing. These two effects work against each other, and the overall outcome depends on the underlying parameters.

As shown in Figure 4, with $\beta = 3$, shareholder wealth increases monotonously with α

when $L \leq 75$; however, when $L > 75$, shareholder wealth first increases with α, then reaches a maximum level, and finally decreases with α. In fact, when L is low, CoCo conversion is triggered only when significant losses are recorded; as a result, the positive effect of protection largely overcomes the negative effect of dilution, and this positive effect get strengthened when increasing α. On the other hand, when L is high, the positive effect prevails only when α is sufficiently low; when α reaches a certain level, the negative effect of dilution begins to prevail.

(Insert Figure 4 here)

3) Impact of σ, the volatility of the bank's assets

In the absence of CoCo bond (i.e., $\alpha = 0$), the bank is only financed with common stocks and a traditional zero-coupon bond as in the model of Black-Scholes-Merton. In this case, shareholder wealth can be considered as a traditional European call option, and its value increases monotonously with σ, the volatility of the underlying asset. Figure 5 displays the same trend with our standard parameters when we vary α from 0 to 1.

(Insert Figure 5 here)

However, Figure 5 shows that, for banks with a higher α, shareholder wealth increases more slowly with σ than for banks with a lower α. This can be explained by the fact that α indicates the proportion of bondholders sharing risks with shareholders. When α is low, shareholders bear most of the bank's risk, and their wealth is sensitive to the volatility resulting from its investment policy. On the other hand, when α is high, shareholders are not alone in assuming the bank's risk, but share this risk with CoCo bondholders. In this case, shareholder wealth is less sensitive to the bank's risk, represented by σ.

4) Impact of L, the trigger level

Figure 6a shows that when β is low (i.e., $\beta \leq 1$), shareholder wealth increases monotonously with L, the conversion trigger. In fact, when β is low, CoCo conversions' dilution effect is not significant, while their protection feature prevails. In this case, the higher L is, the more CoCo bonds protect shareholders, and so the greater shareholder wealth is.

(Insert Figure 6a here)

However, when beta is high (i.e., $\beta \geq 2$), shareholder wealth first increases with the trigger when L is low, reaches a maximum at a certain level noted as L_{max}, and then decreases with the trigger as L continues to rise. This phenomenon can be explained as follows: if L is low, CoCo conversion will be triggered only when significant losses will be recorded, and increasing the trigger level improves shareholders' protection against bankruptcy; this explains the increase in shareholder wealth. However, when L reaches a certain level, CoCo conversion will be triggered as soon as the bank begins to make losses, and increasing the trigger level amplifies CoCo bonds' dilution effect even more; this explains the decrease in shareholder wealth. This property is particularly important when designing CoCo bonds: once β is fixed, it is in shareholders' interest to choose an appropriate trigger level to maximize their wealth. Figure 6b illustrates this evolution with $\beta = 3$.

(Insert Figure 6b here)

Figure 6c confirms the outcomes of Figures 6a and 6b by showing how the optimal trigger level (L_{max}) moves with β for different values of σ. First, it shows that L_{max} decreases with β for a given σ. Actually, when β is low, CoCo bonds' dilution effect is barely significant. When we raise L, the positive impact of protection prevails over the negative impact of dilution effect. However, when L reaches a certain level, these two impacts counterbalance each other, which explains the high level of L_{max} when β is low. On the other hand, when β is high, CoCo bonds' dilution effect is significant. When we raise L, the negative impact of dilution effect will be even more significant, and the optimal trigger level at which the two impacts neutralize each other will be reached "quickly" or at a relatively low level.

(Insert Figure 6c here)

Figure 6c also shows that L_{max} decreases with σ for a given β. In fact, as explained previously, when we raise the trigger at a low level, the value of the bank's assets increases because the positive effect of protection increases more quickly than the negative effect of dilution. However, as the trigger increases progressively, the increase in the positive effect slows down, while the increase in the negative effect accelerates until the two opposing effects counterbalance each other at a certain level, L_{max}. In this movement, banks with different volatility behave differently. For banks with lower volatility, the value of their assets fluctuates less than banks with higher volatility. As a result, when we raise the trigger, even though the CoCo conversion probability increases, it increases less than banks with higher volatility. For this reason, the optimal trigger level at which the positive and negative effects neutralize each other will be reached more "slowly" or at a relatively high level.

Figure 6d shows that, for a given α, shareholder wealth first increases with L, then reaches its maximum at L_{max}, and finally decreases with the variable. To note that all the optimal triggers are close to 85 regardless of the value chosen for α, as long as the standard parameters are kept for other variables.

(Insert Figure 6d here)

With B = 90, r = 2% and T = 3 years, we have: $Be^{-rT} = 84.8 \cong 85$. This means that, whatever is α, the CoCo bond proportion, the optimal trigger for the shareholders is close to the present value of the risk-free bond whose face value is the same as that of the bank's whole debt. Nevertheless, this result depends on the values chosen for different parameters. For example, as shown in Figure 6d, when values are chosen outside our "standard parameter set" (for example $\beta \neq 3$ or $\sigma \neq 20\%$), the optimal trigger can be different from 85.

Furthermore, we notice that the "optimal" trigger of 85 is also quite close to 87.4, the

CoCo conversion trigger[5] corresponding to the regulatory leverage ratio of 3%. This result cannot be considered as a general observation, because it also depends on the values chosen for different parameters. Nevertheless, it helps banks to realize how important it is to choose the right trigger when designing their CoCo bonds. In fact, if the optimal trigger is in accordance with the regulatory minimum, capital requirements are no longer in conflict with shareholders' interests which are the maximization of their wealth. Otherwise, if the optimal trigger is higher (or lower) than the regulatory minimum, it means that the conversion ratio is too low (or high) and/or the bank's investments are not risky enough (or too risky). In this case, banks can revise the characteristics of the CoCo bonds and their investment policy so that shareholders' interests are in line with regulators' objectives.

5) Summary of numerical analysis

Numerical results show that shareholder wealth decreases with the conversion ratio β due to the "dilution effect" of CoCo bonds. However, the impact of the proportion of CoCo bond, α, is ambiguous, due to two opposing effects: a higher α provides shareholders with better bankruptcy protection, but it also leads to greater dilution in terms of capital control and profit sharing. Similarly, the impact of the volatility σ is ambiguous, due to two opposing effects: higher volatility increases shareholder wealth by providing a higher expected return while limiting their losses to the initial investment; but higher volatility also makes CoCo conversion more likely, and this may damage shareholder wealth because of dilution effect.

The most interesting numerical result concerns the impact of conversion trigger. When the other variables are chosen, shareholder wealth reaches its maximum when the trigger level stands at L_{max}. With the "standard parameters" used in this paper (i.e., $V_0 = 100$, $B = 90$, $r = 2\%$, $T = 3$ *years*, $\sigma = 20\%$, $\alpha = 0.3$, $\beta = 3$), we have: $L_{max} = 85$. This "optimal level" is close

[5] Remember that with the "standard parameters," we choose $L = \frac{Be^{-rT}}{1-l^*} = \frac{90\times e^{-2\%\times 3}}{1-3\%} = 87.4$ as the trigger threshold for the sum of the bank's assets (see §2.3).

to the present value of a risk-free bond whose face value is the same as the face value of the bank's debt. It is also quite close to the trigger level corresponding to the regulatory minimum of 3% for the equity leverage ratio. These results cannot be generalized because they depend on the values chosen for the parameters.

4. Conclusion

This paper examines the impact of Debt-To-Equity CoCo bonds on the capital structure of a bank financed with equity, a tranche of classic zero-coupon bond, and a tranche of CoCo zero-coupon bond. As in the Black and Scholes model, the sum of the bank's assets is assumed to follow a Geometric Brownian Motion. CoCo bonds will be converted into a certain amount of stocks when the equity leverage ratio reaches a predetermined threshold. Within this framework, shareholder wealth can be considered as the sum of two European call barrier options, and its analytical formula can be derived. Based on this model, numerical analysis shows that CoCo bonds usually increase shareholder wealth by reducing bankruptcy risk, until the dilution effect offsets this positive impact.

The finding obtained in this paper can be beneficial for banks, investors and regulators in several ways. First, leverage ratios are used for the first time to trigger equity conversion instead of traditional capital ratios. Based on non-risk-weighted-assets, leverage ratios are less biased than traditional capital ratios which are based on risk-weighted assets. They are therefore more effective in alerting of an early-stage risk. Therefore, CoCo bonds with leverage ratios as triggers can better fulfil their function as "going-concern" capital by triggering in time the "bail-in" process to avoid a government "bail-out". In this sense, they can better reinforce banks' solvency and so better enhance the financial stability. Second, our finding is consistent with the statement according to which CoCo bonds increase shareholder wealth and firm value by reducing the probability of costly bankruptcy or bailout. Finally, our study highlights the importance to choose properly the various parameters when designing CoCo bonds. For example, when all other parameters are fixed, a right choice of the trigger level allows shareholders to maximize their wealth. Furthermore, if parameters are chosen so that the "optimal trigger level" is in line with the minimum ratio required by regulation, regulatory requirements are no longer simple constraints, but are transformed into a motivation for shareholders to maximize their wealth. In case such an objective is achieved, shareholders' (financial) interests are henceforth reconciled with regulators' (risk prevention) objectives.

Regarding future research, it would be interesting to examine the capital structure of banks which are financed with two tranches of CoCo bonds, a "junior" one with a high trigger and a "senior" one with a low trigger. The "junior" tranche aims to prevent risks when the bank is still in good health, while the "senior" tranche focuses on rescuing the bank when it is already in a distressed situation.

REFERENCES

Acharya V. V., and M. Richardson (2009), *Restoring Financial Stability*, John Wiley & Sons, Inc., Hoboken, New Jersey.

Albul B., Jaffee D.M., Tchistyl A. (2016), "Contingent Convertible Bonds and Capital Structure Decisions", https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2772612.

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

Barclays (2014) "The CoCo Handbook Vol. 4", *Credit Research of Barclays*, 12 June.

Barucci E., and L. Del Viva (2012), "Countercyclical contingent capital", *Journal of Banking and Finance*, 36(6), 1688-1709.

Barucci E., and L. Del Viva (2013), "Dynamic capital structure and the contingent capital option", *Annals of Finance*, 9(3), 337-364.

Basel Committee on Banking Supervision (2013), *Regulatory Consistency Assessment Programme (RCAP): Analysis of risk-weighted assets for credit risk in the banking book*, http://www.bis.org/publ/bcbs256.pdf, July.

Berg T., Kaserer C. (2015), "Does Contingent Capital Induce Excessive Risk-Taking?", *Journal of Financial Intermediation*, 24(3), 356-385.

Bishop, D., Zuofei Liu, E., Murray, P., Solomonia, T. (2010), "Contingent Convertible Bonds: Comments on the December 2009 Consultative Document - Strengthening the Resilience of the Banking Sector", Working paper.

Bjorn-Nordal K., Stefano N. (2014), "Contingent Convertible Bonds (CoCos) Issued by European Banks", Staff Memo, Norges Bank.

Black F., and M. Scholes, M. (1973), "The Pricing of Options and Corporate Liabilities", *Journal of Political Economy*, 637-654.

Bleich D. (2014), “Contingent Convertible Bonds and the Stability of Bank Funding: the Case of Partial Writedown”, Discussion Paper, Deutsche Bundesbank, N°28.

Brigo D., Garcia J., Pede N. (2015) “CoCo Bonds Pricing with Credit and Equity Calibrated First-Passage Firm Value Model”, *International Journal of Theoretical and Applied Finance*, 18(3), 1-13.

Calomiris C. W., and R. J. Herring (2013), “How to Design a Contingent Convertible Debt Requirement that Helps Solve Our Too-Big-To-Fail Problem”, *Journal of Applied Corporate Finance*, 25(2), 39-62.

Chesney M., and R. Gibson-Asner (1999), “The investment policy and the pricing of equity in a levered firm: a re-examination of the 'contingent claims' valuation approach”, *European Journal of Finance*, Taylor and Francis Journals, vol. 5(2), pages 95-107, June.

Culp C. L. (2009), “Contingent capital vs. contingent reverse convertibles for banks and insurance companies”, *Journal of Applied Corporate Finance*, 21(4), 17-27.

De Martino G., M. Libertucci, M. Marangoni, and M. Quagliariello (2010), “Countercyclical contingent capital (CCC): possible use and ideal design”, Bank of Italy Occasional Paper, No. 71.

De Spiegeleer J., and W. Schoutens (2012), “Pricing contingent convertibles: a derivatives approach”, *The Journal of Derivatives*, 20(2), 27-36.

De Spiegeleer J., Van Hulle C., Schoutens W. (2014), *The Handbook of Hybrid Securities: Convertible Bonds, CoCo Bonds and Bail–In*, John Wiley & Sons.

Flannery M. J. (2005), “‘No Pain, Ni Gain’: Effecting Market Discipline via ‘Reverse Convertible Debentures,’” in Hal Scott (ed.), *Capital Adequacy beyond Basel: Banking, Securities, and Insurance*, Oxford University Press, Oxford.

Flannery M. J. (2009a), “Stabilizing Large Financial Institutions with Contingent Capital Certificates”, Working Paper, Federal Reserve Bank of New York, October 5.

Flannery, M. J. (2009b), “Market-Valued triggers will work for Contingent Capital instruments”, Solicited Submission to U.S. Treasury Working Group on Bank Capital, November 6.

Flannery, M., Perotti, E. (2011), “CoCo design as a risk preventive tool”, VOX - Research-based policy analysis and commentary from leading economists.

Glover J., Bearsworth T. (2016), “Contingent Convertible, High Yield Hand Grenades”, Bloomberg Quick Take.

Goldman Sachs, Global Markets Institute (2011), “Contingent capital: possibilities, problems and opportunities”.

Hart O., Zingales L. (2010), “How to make a bank raise equity”, *Financial Times*, February 7.

Hilscher J., Raviv A. (2012), “Bank stability and market discipline: the effect of contingent capital on risk taking and default probability”, Working Paper, Brandeis University.

Lai R. N., and R. Van Order (2011), “CoCo bonds as an impediment to more risk-taking and an alternative to bankruptcy in mortgage markets”, AFA conference at Chicago.

Li J., Metzler A., Reesor R.M. (2017), “A Structural Framework for Modelling Contingent Capital”, *Quantitative Finance*, 17(7), 1071-1088.

McDonald R. L. (2010), “Contingent capital with a dual price trigger”, Northwestern University Working Paper.

Merton R.C. (1973), “Theory of rational option pricing”, *Bell Journal of Economics and Management Science*, 29, 449-470.

Pennacchi G. (2010), "A Structural Model of Contingent Bank Capital", FRB of Cleveland Working Paper No. 10-04, April 23.

Pennacchi G., T. Vermaelen, and C. Wolff (2014), "Contingent capital: the case for COERCs", *Journal of Financial and Quantitative Analysis*, 49(3), 541-574.

Rich D. R. (1994), "The Mathematical Foundations of Barrier Option-Pricing Theory", *Advances in futures and options research*, Volume 7, 267-311.

Schmid M. (2014) "Investing Contingent Convertibles", Crédit Suisse.

Schmidt C., Azami T.F. (2015), "The Impact of CoCo Bonds on Bank Value and Perceived Default Risk: Insights and Evidence from Their Pioneering use in Europe", *The Journal of Applied Business Research*, December (31), 2297-2306.

Squam Lake Group (2010), *The Squam Lake Report: Fixing the Financial System*, Princeton University Press, Princeton, New Jersey, USA.

Von Furstenberg G. (2011), "Contingent capital to strengthen the private safety net for financial institutions: CoCos to the rescue?", Deutsche Bundesbank Working Paper.

Wilkens S., Bethke N. (2014), "Contingent Convertible (CoCo) Bonds: A First Empirical Assessment of Selected Pricing Model", *Financial Analysts Journal*, 70(2), March-April, 59-77.

Williams-Grut O. (2016), "Here is what CoCo bonds are and why investors are freaking out about them", *Business Insider*, UK Finance, February.

Figure 1: Capital structure of the bank

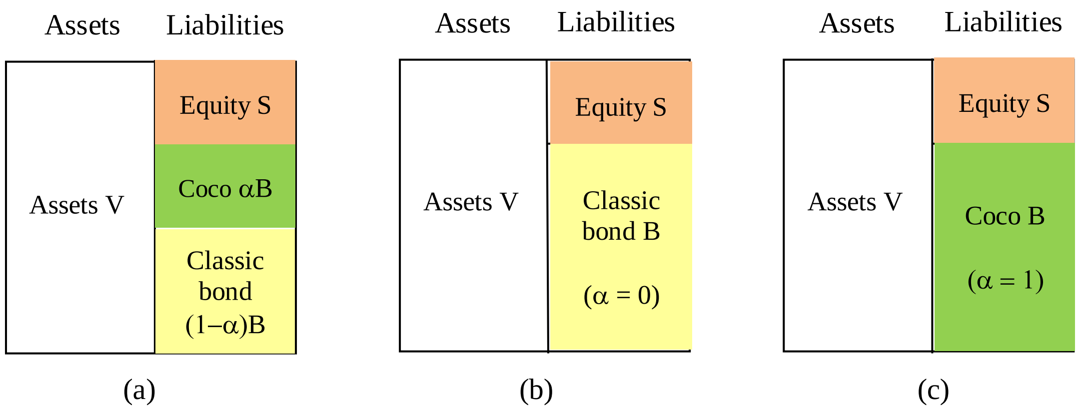

Figure 2: CoCo bond conversion mechanism

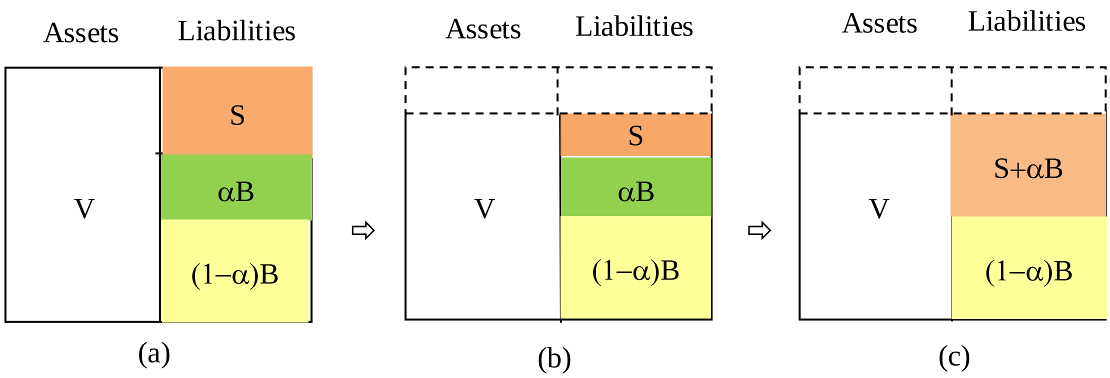

Table 1: Some examples of CoCo bonds issued by European banks

Issuer	Date	Maturity	Mechanism	Trigger	Coupon	Currency	Size (million)
Lloyds	12/2009	2019/2020/ Perpetual	Debt to Equity	5%	12%	GBP	8500
Rabobank	3/2010	3/2020	Write-Down	7%	6.875%	EUR	1250
UniCredit	7/2010	Perpetual	T. W-Down (*)	6%	9.375%	EUR	500
Intésa Sanpaolo	10/2010	Perpetual	T. W-Down (*)	6%	9.5%	EUR	1000
Rabobank	1/2011	Perpetual	Write-Down	8%	8.375%	USD	2000
Crédit Suisse	2/2011	2/2041	Debt to Equity	7%	7.875%	USD	2000
Allied Irish Bank	7/2011	7/2016	Debt to Equity	8.25%	10%	EUR	1600
Bank of Ireland	7/2011	7/2016	Debt to Equity	8.25%	10%	EUR	1000
Rabobank	11/2011	Perpetual	Write-Down	8%	8.375%	USD	2000
Zurich Kantonal Bank	1/2012	Perpetual	Write-Down	7%	3.5%	CHF	590
UBS	2/2012	2/2022	Write-Off	5%	7.25%	USD	2000
Crédit Suisse	3/2012	3/2022	Debt to Equity	7%	7.125%	CHF	750
Banco Popular Espanol	6/2012	3/2014	Debt to Equity	7%	8.5%	EUR	1500
UBS	8/2012	8/2022	Write-Off	5%	7.625%	USD	2000
Barclays	11/2012	11/2022	Write-Off	7%	7.625%	USD	3000
Bank of Ireland	1/2013	7/2016	Debt to Equity	7%	10%	EUR	1000
KBC	1/2013	1/2023	Write-Off	7%	8%	USD	1000
Swiss Re	3/2013	9/2024	Write-Off	5.125%	6.375%	USD	750
Barclays	4/2013	4/2023	Write-Off	7%	7.75%	USD	1000
BBVA	4/2013	Perpetual	Debt to Equity	7%	9%	USD	1500
UBS	5/2013	5/2023	Write-Off	5%	4.75%	USD	1500
Crédit Suisse	8/2013	8/2023	Write-Off	5%	6.5%	EUR	2500
Crédit Suisse	9/2013	8/2025	Write-Off	5%	5.75%	EUR	1250
Crédit Agricole	9/2013	9/2023	Write-Off	7%	8.125%	USD	1000
Société Générale	9/2013	Perpetual	T. W-Down (*)	5.125%	8.25%	USD	1250
Banco Popular Espanol	10/2013	Perpetual	Debt to Equity	5.125% - 6% Dual-trigger (**)	11.5%	EUR	500
Barclays	11/2013	Perpetual	Debt to Equity	7%	8.25%	USD	2000
Barclays	12/2013	Perpetual	Debt to Equity	7%	8%	EUR	1000
Crédit Suisse	12/2013	Perpetual	Write-Off	5%	7.5%	EUR	1250
Société Générale	12/2013	Perpetual	T. W-Down (*)	5.125%	7.875%	USD	1750
Crédit Agricole	1/2014	Perpetual	T. W-Down (*)	5.125% - 7% Dual-trigger (***)	7.875%	USD	1750
UBS	2/2014	2/2021	T. W-Down (*)	5%	4.75%	EUR	2000
BBVA	2/2014	Perpetual	Debt to Equity	5.125%	7%	EUR	1500
Santander	3/2014	Perpetual	Debt to Equity	5.125%	6.25%	EUR	1500
Dansk Bank	3/2014	Perpetual	T. W-Down (*)	7%	5.75%	EUR	750
KBC	3/2014	Perpetual	T. W-Down (*)	5.125%	5.625%	EUR	1400

Source: Bloomberg

(*) "T.W-Down" means "Temporary Write-Down". With this, the repayment amount of the CoCo bond is reduced when the trigger indicator falls below the trigger threshold. However, once the trigger indicator comes back above the threshold, the repayment amount is restored.

(**) The trigger event happens if 1) the CET1 ratio reaches 5.125%, or 2) the Tier 1 ratio reaches 6%.

(***) The trigger event happens if 1) Crédit Agricole SA's CET1 Capital Ratio reaches or falls below 5.125%, or 2) the Crédit Agricole Group's CET1 Capital Ratio reaches or falls below 7%.

Figure 3a: Shareholder wealth (S_0) as a function of β (and α)
(with V_0 = 100, B = 90, r = 2%, T = 3 years, σ = 20%, L = 87.4)

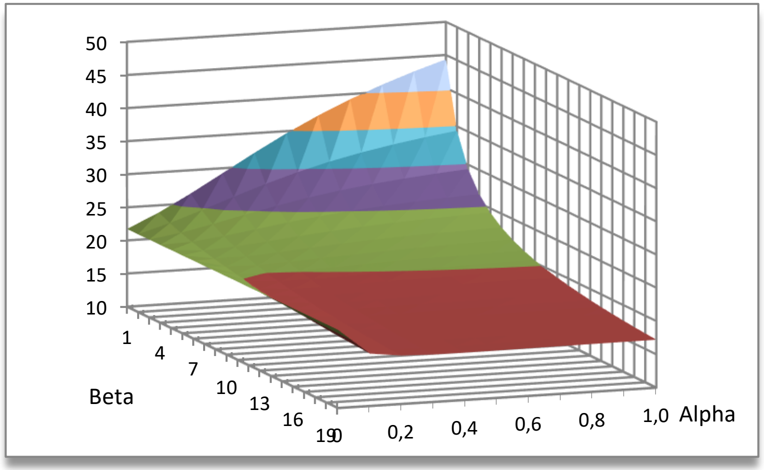

Figure 3b Shareholder wealth (S_0) as a function of β (and L)
(with V_0 = 100, B = 90, r = 2%, T = 3 years, σ = 20%, α = 0.3)

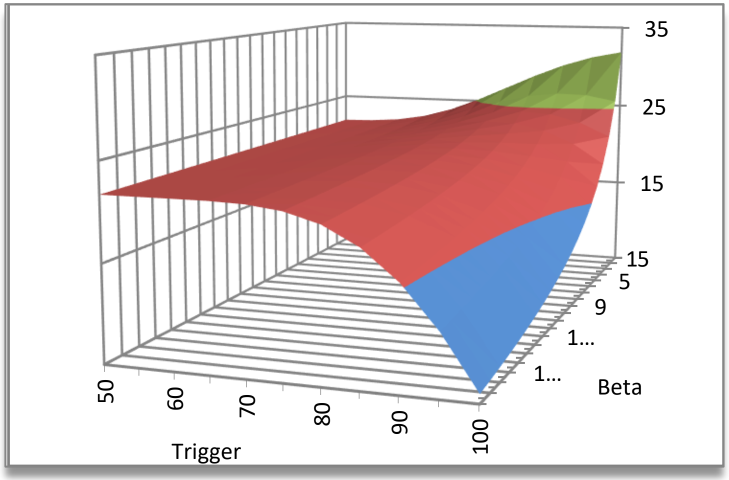

Figure 4: Shareholder wealth (S_0) as a function of α
(with V_0 = 100, B = 90, r = 2%, T = 3 years, σ = 20%, β = 3)

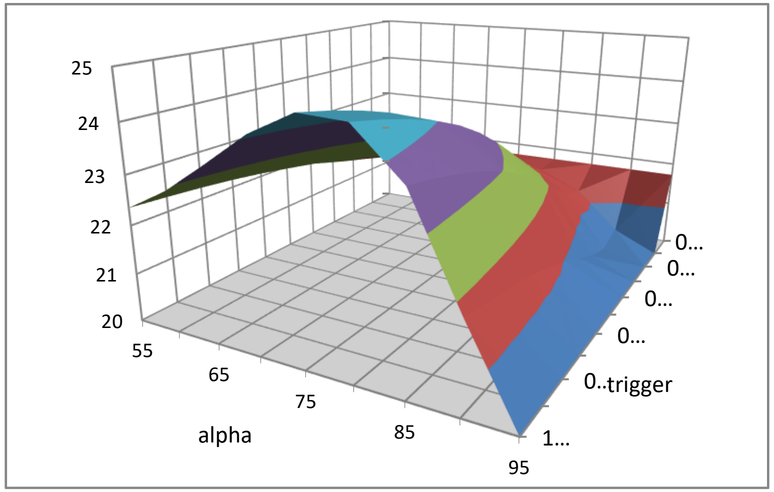

Figure 5: Shareholder wealth (S_0) as a function of σ (and α)
(with V_0 = 100, B = 90, r = 2%, T = 3 years, β = 3, L = 87.4)

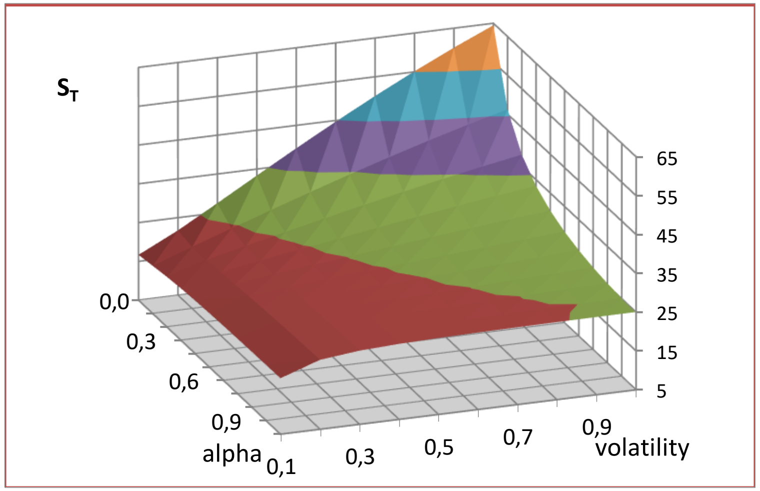

Figure 6a: Shareholder wealth (S_0) as a function of the trigger level (L)
(with V_0 = 100, B = 90, r = 2%, T = 3 years, σ = 20%, α = 0.3)

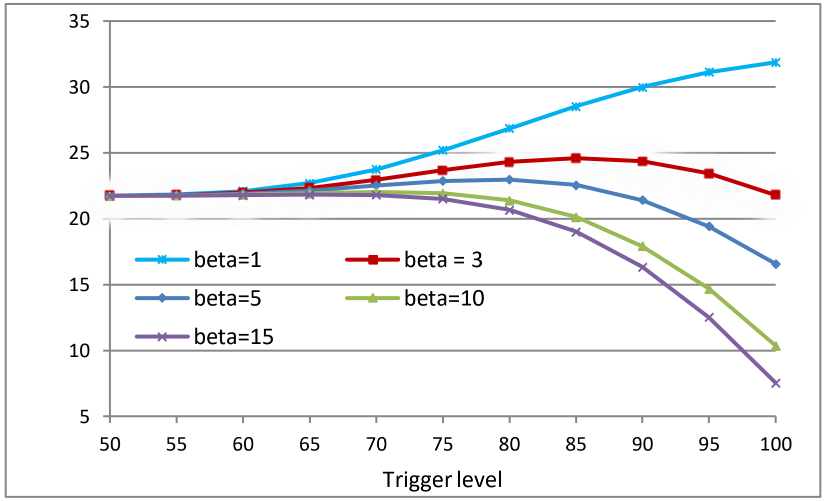

Figure 6b: Shareholder wealth (S_0) as a function of the trigger level (L)
(with V_0 = 100, B = 90, r = 2%, T = 3 years, σ = 20%, α = 0.3)

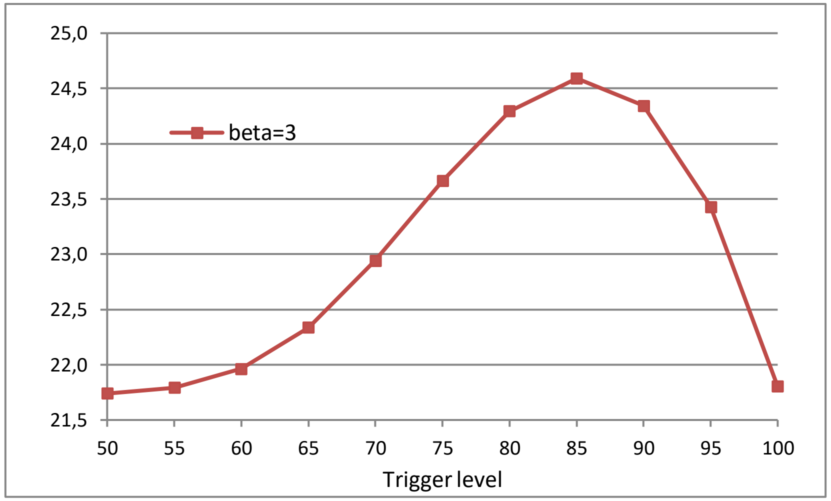

Figure 6c: The optimal trigger level (L_{max}) as function of conversion ratio (β)
(with V_0 = 100, B = 90, r = 2%, T = 3 years, α = 0.3)

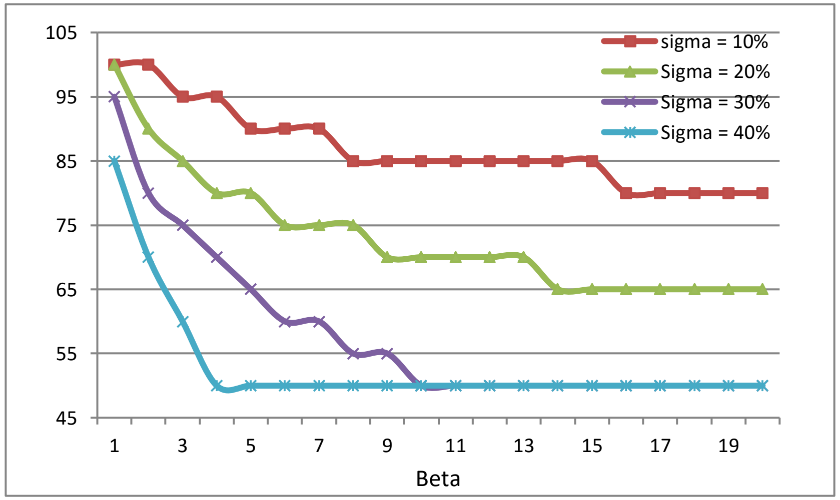

Figure 6d: Shareholder wealth (S_0) as a function of L
(with V_0 = 100, B = 90, r = 2%, T = 3 years, σ = 20%, β = 3)