https://economix.fr/

Mind the Conversion Risk: a Theoretical Assessment of Contingent Convertible Bonds

Document de Travail
Working Paper
2019-5

Gaëtan Le Quang

EconomiX - UMR7235
Université Paris Nanterre
Bâtiment G - Maurice Allais, 200, Avenue de la République
92001 Nanterre cedex

Email : secretariat@economix.fr

Mind the Conversion Risk: a Theoretical Assessment of Contingent Convertible Bonds

Gaëtan Le Quang*

March 20, 2019

Abstract: We develop a theoretical model to assess the merits of principal-write down contingent convertible (CoCo) bonds. The conversion risk is the key feature of CoCo bonds. Because of this conversion risk, CoCo bonds are hard to price and an equilibrium price does not necessarily exist. In our model, for such a price to exist, the bank needs to hold a minimum amount of equity and/or the expected return associated with its asset portfolio needs to be large enough. When an equilibrium price exists, it is a decreasing function in the amount of equity held by the bank. Well-capitalized banks can thus issue CoCo bonds at a lower price than least-capitalized banks. This is the reason why CoCo bonds are to be thought of more as a complement to equity than as a substitute. In addition, because of the conversion risk, self-fulfilling panics may occur in the CoCo bonds' market. We indeed define a game between CoCo bonds' holders and the Central Bank that allows us to exhibit situations where a panic occurs in the CoCo bonds' market. Using the global game technique, we show that the probability of crisis can be expressed as a function of the return associated with the asset portfolio of the bank. The probability of crisis is shown to be sensitive to the precision of the information available to CoCo bonds' holders. Taken together, our results call for cautiousness when assessing the relevance of regulatory requirements in CoCo bonds, especially concerning their systemic impact.

Keywords: convertible contingent bonds; conversion risk; equity; banks; systemic risk

JEL codes: G13; G21; G28; G32; G33

*EconomiX (UMR7235), GATE-LSE (UMR5824) and Université Paris-Nanterre, 200 Avenue de la République, 92001 Nanterre cedex, France. E-mail: glequang@parisnanterre.fr

1 Introduction

Regulatory capital may be the hottest issue post-crisis banking regulation has to tackle. This problem actually raises two intertwined questions: that of the very definition of regulatory capital and that of the setting of minimum requirements. Basel III has moved forward on those two problems. First, the definition of regulatory capital has been narrowed and many hybrids that were previously considered as capital are no longer admitted as such. Second, minimum requirements have been augmented and counter-cyclical cushions added. Some doubts however remain concerning the ability of the new capital requirements to ensure the soundness of the banking system and thus to prevent costly bailouts from occurring. Implementing a minimum requirement of properly designed contingent convertible (CoCo) bonds is one of the proposals that have been put forward to strengthen capital requirements. The Squam Lake Working Group (2009) for instance praises those instruments and strongly advocates for their inclusion in banking regulation:

> We recommend support for a new regulatory hybrid security that will expedite the recapitalization of banks. This instrument resembles long-term debt in normal times, but converts to equity when the financial system and the issuing bank are both under financial stress. The goal is to avoid *ad hoc* measures such as those taken in the current crisis, which are costly to taxpayers and may turn out to be limited in effectiveness. The regulatory hybrid security we envision would be transparent, less costly to taxpayers, and more effective. (Squam Lake Working Group, 2009, p. 2)

In this paper, we develop a theoretical model to study the issues raised by the conversion risk associated with CoCo bonds. We model a bank that relies on three different funding sources: capital (equity), regular bonds and CoCo bonds. CoCo bonds are assumed to be written off whenever the capital of the bank falls below a pre-defined threshold. This is how the conversion risk materializes in the model. We first show that because of the conversion risk, the bank is not always able to issue CoCo bonds. Specifically, when the bank is not capitalized enough and/or the expected return associated with the asset side of its balance sheet is too low, it is not possible to find an equilibrium value for the return associated with CoCo bonds. When such an equilibrium return exists, we show that it is a decreasing function in the amount of capital held by the bank. In other words, well-capitalized banks are able to issue CoCo bonds at a lower price than less well-capitalized banks. CoCo bonds cannot therefore be thought of as a substitute for equity but are to be used more as a complement by already well-capitalized banks. We perform a loss analysis that shows that weakly-capitalized banks cannot indeed take full advantage of CoCo bonds, either because CoCo bonds are very costly for those banks or because they cannot issue any CoCo bond at all. The conversion risk associated with CoCo bonds cannot only be assessed from a micro perspective. The main threat associated with conversions is indeed that they could act as a transmission channel for systemic risk. To assess whether or not the conversion risk can be a factor of systemic risk, we define a game between CoCo bonds' holders and the Central Bank. Doing so we show that self-fulfilling panics can arise because CoCo bonds' holders are incentivized to sell their bonds when they expect that the Central Bank is about to force their conversion, while the Central Bank is incentivized to force such a conversion when panic sales of CoCo bonds are expected. Precisely, we show that a crisis is more likely to occur when those who have invested in CoCo bonds are sophisticated investors, in the sense that they benefit from accurate private information. On the contrary, the more the information found in the financial statements of the bank is precise, the less likely a crisis is to occur.

CoCo bonds are hybrid securities that are characterized by two main features (Avdjiev *et al.*, 2013): a trigger that modifies the repayment terms and a loss-absorption mechanism. Conversion can specifically be triggered either mechanically – for instance whenever the capital of the bank falls below a pre-defined threshold – or discretionarily – in which case the regulatory institution in charge of the bank decides when to trigger the conversion. This conversion can either lead to write CoCo bonds down or to turn them into common equity. Depending on the way those two features are set – i.e. the trigger and the loss-absorption mechanism – CoCo bonds can either act in a gone-concern or in a going-concern perspective. For instance, a CoCo bond that would be converted into equity whenever the bank got insolvent would act in a gone-concern perspective, the main purpose being here to protect taxpayers from costly bailouts. The regulatory standards that aim at ensuring a bail-in instead of a bailout in the event of a crisis and that are currently being implemented – i.e. the Total Loss Absorbing Capacity (TLAC) and the Minimum Requirement for own funds and Eligible Liabilities (MREL) – thus allow properly designed CoCo bonds to enter eligible liabilities. CoCo bonds can also be seen in a going-concern perspective: the willingness to avoid costly conversions of CoCo bonds into equity could incentivize banks to better manage the risk associated with their asset portfolio.

CoCo bonds are recent financial instruments. In 2009, LLoyds issued what was called "enhanced capital notes", which can be considered as the first CoCo bonds ever issued. Those notes would automatically be converted into equity whenever LLoyds' core Tier 1 capital would fall below 5%. In 2011, the Credit Suisse issued in turn two billions francs worth of CoCo bonds. Those CoCo bonds have a dual trigger: their conversion into equity is triggered either by a regulatory decision or whenever the Credit Suisse ratio of equity over risk-weighted assets falls below 7%. In May 2013, BBVA issued for the first time coupon cancellable CoCo bonds. The novelty is that when the conversion is triggered, coupons are cancelled but the CoCo bond is not converted into equity. According to Avdjiev *et al.* (2017) banks all around the world issued a total of $521 billions in CoCo bonds between 2009 and December 2015. Those authors additionally point out that large and strong banks are more likely to issue CoCo bonds than banks in need of recapitalization. This is in line with one of the main results derived from our theoretical model according to which weakly capitalized banks may find it difficult to issue CoCo bonds.

The literature on CoCo bonds has been constantly growing in the last few years. Flannery (2005) was a precursor when he discussed what he called "reverse convertible debentures" whose main features were close to those of CoCo bonds. More recently, the Squam Lake Working Group (2009), MacDonald (2013), Pennacchi *et al.* (2014) and Flannery (2016) have defended the idea of contingent capital requirements. Among the advantages associated with CoCo bonds, their ability to provide banks with the incentives to manage safely their balance sheet is particularly put forward. Himmelberg and Tsyplakov (2014) indeed show that if conversion is dilutive for existing shareholders, CoCo bonds may provide managers with the incentives to reduce the likelihood of conversion by maintaining high capital ratios.

Because of the conversion risk, pricing CoCo bonds is however a tricky exercise. Glasserman and Nouri (2012) manage to derive closed-form expressions for the market value of CoCo bonds associated with a capital-ratio trigger when the firm's asset value is modeled as a geometric Brownian motion. Glasserman and Nouri (2016) show that for a pricing equilibrium to exist in the case of a stock price trigger, the conversion should be disadvantageous to shareholders. For CoCo bonds associated with a market trigger based on common equity price, Sundaresan and Wang (2015) show that the pricing equilibrium is not necessarily unique. For the equilibrium to be unique, the conversion must not transfer value from equity holders to CoCo bonds investors. Pennacchi and Tchistyi (2019) however point out an error in the paper by Sundaresan and Wang (2015) that amends their results. Pennacchi and Tchistyi (2019) indeed show that, the error made by Sundaresan and Wang (2015) once corrected, they obtain an equilibrium price very similar to that found by Glasserman and Nouri (2016).

Koziol and Lawrenz (2012) show that CoCo bonds distort risk-taking incentives and therefore conclude that those instruments should be used with great caution. Goodhart (2010) does not believe that CoCo bonds will be able to fulfill their main objective since banks in distress mostly need cash, which CoCo bonds are not able to provide. Furthermore, Goodhart (2010) recalls that the assessment of CoCo bonds cannot only focus on their expected impact on one particular bank but should also take their impact on the financial system as a whole into account. As Allen (2012) states it, expectations of conversions can indeed lead to panic sales and CoCo bonds can thus weaken the financial system instead of strengthening it. Bologna *et al.* (2018) provide empirical evidence that shows how contagion can spread in the CoCo bonds market. Using two stressed episodes that have affected the European CoCo bonds market in 2016, the authors show that there exists a significant CoCo bonds-specific contagion that can be the consequence of the reassessment by investors of CoCo bonds' riskiness. Corcuera *et al.* (2014) state that because of the conversion risk, CoCo bonds exhibit a death-spiral effect. To hedge the conversion risk, CoCo bonds' holders may indeed short sell shares. Doing so they may find themselves in a position of selling shares whose price is decreasing and therefore they may contribute actively to the materialization of the conversion risk. By hedging the conversion risk, investors thus make it more likely. Hence the spiral effect. Corcuera *et al.* (2014) however show that such a death-spiral effect is less likely to materialize for coupon cancellable CoCo bonds than for CoCo bonds that convert into equity.

Because CoCo bonds are hard to price and can spark off a crisis in financial markets due to contagion mechanisms, they can fail to fulfill their objective of strengthening the soundness of the financial system. Admati *et al.* (2013) therefore call for a sharp increase in equity requirements instead of implementing regulatory requirements in hybrid securities. Their main argument is based on a debunking of the myth according to which equity is costly. They indeed state that "the social costs of significantly increasing equity requirements for large financial institutions would be, if there were any at all, very small." (Admati *et al.*, 2013, p.1).

We model a bank that invests in an asset portfolio. The bank relies on three funding sources: equity, CoCo bonds and regular bonds. Contrary to Glasserman and Nouri (2012, 2016) we consider principal write-off CoCo bonds instead of CoCo bonds that convert into common equity. We show that it is not always possible to find an equilibrium price for CoCo bonds. In particular, CoCo bonds are either impossible to issue or very costly for weakly-capitalized banks. Those banks cannot therefore take full advantage of CoCo bonds. To study under which circumstances a crisis occurs in the CoCo bonds' market we then define the following game: investors decide to sell their CoCo bonds when they expect those CoCo bonds to be converted while the Central Bank decides to force the conversion of CoCo bonds when she fears that they would be massively panic sold. To solve this game we resort to the global game technique (Carlsson and Van Damme, 1993; Morris and Shin, 1998; Metz, 2002; Morris and Shin, 2003; Morris and Shin, 2004). We thus assume that investors do not know the true financial situation of the bank. They are granted a public signal that accounts for the information displayed by the bank in its financial statements. Additionally, we assume that each investor has its own assessment of the situation of the bank. This assessment is based on elements that are not found in the financial statements but relies on the "sophistication" of investors. This second source of information is referred to as the private signal. Investors therefore base their decisions on two noisy signals that are informative of the financial situation of the bank.

To our knowledge this paper is the first to demonstrate through a theoretical framework the idea that CoCo bonds can somehow be considered as a complement to equity when banks are already well-capitalized while they are a poor option for banks that suffer from under-capitalization. In addition it is also the first to theoretically inquire how a panic can materialize in the CoCo bonds' market.

The next section presents the general framework of the model. Section 3 introduces

CoCo bonds and develops a simple pricing model. In section 4, we present the loss analysis and compute the optimal proportion of CoCo bonds. Section 5 develops a game that allows us to study how a panic can materialize in the CoCo bonds' market. Section 6 discusses policy implications. Section 7 concludes.

2 General framework

There are two periods. In $t = 0$, the bank invests in an asset portfolio that yields a random return θ. This portfolio is funded thanks to both capital and bonds. In $t = 1$, the asset portfolio pays and creditors are paid. We consider two types of bonds: regular bonds and CoCo bonds. Creditors are in all cases assumed to be risk-neutral. Let us denote by y the proportion of bonds and by K_0 the capital in $t = 0$. We therefore know that $K_0 + y = 1$.

3 A first glimpse into CoCo bonds

3.1 Definition

We assume here that y is entirely made of CoCo bonds. CoCo bonds are associated with a capital trigger that forces their principal to be written off whenever the capital of the bank falls below a certain threshold. Let us denote by r_2 the return associated with those CoCo bonds. We assume that CoCo bonds are written off whenever the value of the capital in $t = 1$ is below 0.[1] That is when:

$$\underbrace{\theta - yr_2}_{K_1} \leq 0 \iff \theta \leq \theta^* \equiv (1 - K_0)r_2. \tag{1}$$

θ^* is the value of θ below which CoCo bonds are written off. Precisely, when $\theta > \theta^*$, CoCo bonds' holders receive a return r_2 per unit they invested in CoCo bonds, while, when $\theta \leq \theta^*$, CoCo bonds are written off and those who have invested in them receive 0. We notice that θ^* is decreasing in K_0: the better capitalized the bank, the smaller the conversion risk. Pricing CoCo bonds requires to take this conversion risk into account since intuitively a high conversion risk would translate into a high value of r_2. We tackle

[1] We could have chosen any linear function of the $t = 0$ capital without any loss of generality.

the pricing issue in the next section.

3.2 Pricing

Let us denote by $f(\cdot)$ the probability density function and by $F(\cdot)$ the cumulative distribution function of the normal distribution with mean μ and variance σ^2. We assume that θ follows this distribution with a left truncation in 0. We therefore denote by $f_t(\cdot)$ the left-truncated probability density function of θ such that $f_t(x) = \frac{f(x)}{1-F(0)}$ for $x \in [0, +\infty[$. We similarly define by $F_t(\cdot)$ the cumulative distribution function of the left-truncated normal distribution of θ. Since creditors are risk-neutral, the expected return associated with CoCo bonds should be equal to the riskless return. We assume that the riskless return is equal to 1. Let us denote by r_2^* the equilibrium value of r_2. r_2^* is thus given by:

$$\int_{\theta^*}^{+\infty} r_2 f_t(\theta) d\theta = 1 \iff \left[1 - F_t\left(\theta^*\right)\right] r_2 = \left[\frac{1 - F\left(\theta^*\right)}{1 - F\left(0\right)}\right] r_2 = 1. \tag{2}$$

Equations (1) and (2) allow us to compute the equilibrium value of r_2. We show that such an equilibrium does not always exist. In other words, the bank is not always able to issue CoCo bonds.

Proposition 1. *There does not necessarily exist an equilibrium value r_2^*. For such an equilibrium to exist, K_0 needs to be larger than a threshold $Kmin$ defined as the minimum on $\mathbb{R}_+^*$ of the function $1 - \frac{1}{x} F_t^{-1}\left(1 - \frac{1}{x}\right)$. $Kmin$ is a decreasing function in μ.*

Proof. See Appendix. □

Figure 1 plots $Kmin$ as a function of μ. When K_0 is below the curve $Kmin$, no equilibrium value of r_2 can be found. In this case, the bank cannot issue CoCo bonds. In accordance with Proposition 1, we indeed notice that $Kmin$ is a decreasing function in μ. In particular, for values of μ larger than approximately 0.8, we have $Kmin < 0$ and thus K_0 is always greater than $Kmin$. In that case, the bank is always able to issue CoCo bonds.

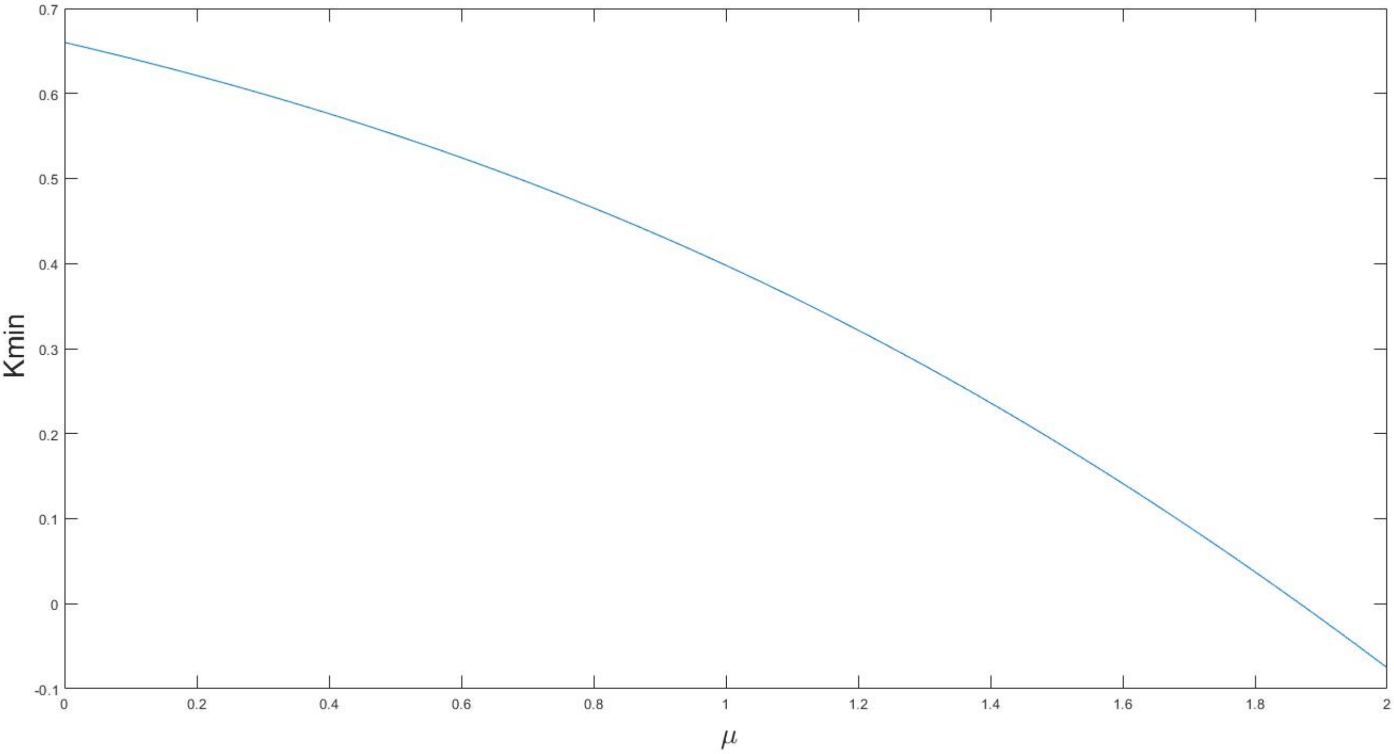

Figure 1: $Kmin$ as a function of μ

Proposition 2. *When an equilibrium return r_2^* exists, it is a decreasing function in K_0 (i.e. $\frac{\partial r_2^*}{\partial K_0} \leq 0$).*

Proof. Assume that r_2^* exists, i.e. $g(r_2) = \left[\frac{1-F(\theta^*)}{1-F(0)}\right] r_2 - 1 = 0$ admits at least one solution and we call r_2^* the smallest value of r_2 for which $g(r_2) = 0$. Let us differentiate r_2^* with respect to K_0:

$$\frac{\partial r_2^*}{\partial K_0} = \frac{-(r_2^*)^2 f(\theta^*)}{1 - F(\theta^*) - (1 - K_0) f(\theta^*) r_2^*}. \tag{3}$$

We notice that (3) can be rewritten as follows:

$$\frac{\partial r_2^*}{\partial K_0} = \frac{-(r_2^*)^2 f(\theta^*)}{[1 - F(0)]\, g'(r_2^*)}. \tag{4}$$

Since r_2^* is the smallest value of r_2 such that $g(r_2) = 0$ and given that $g(0) = -1$, we know that g is increasing on $[r_2^* - \varepsilon, r_2^* + \varepsilon]$ for $\varepsilon > 0$ sufficiently small. Therefore we know that $g'(r_2^*) \geq 0$. In that case we have $\frac{\partial r_2^*}{\partial K_0} \leq 0$. □

Proposition 1 states that weakly-capitalized banks can find themselves unable to issue CoCo bonds. In addition, Proposition 2 states that best-capitalized banks can issue CoCo bonds at a lower price than other banks. Those two propositions provide a theoretical rationale for the empirical evidence according to which larger and stronger banks were among the first wave of CoCo bonds issuers (Avdjiev *et al.*, 2017). Figure 2 plots r_2^* as a function of K_0 for some values of μ. When r_2^* does not exist, we arbitrarily define $r_2^* = 0$. In accordance with Proposition 1, we notice that when μ is small (i.e. $\mu = 1$), the bank is not able to issue CoCo bonds when K_0 is below approximately 0.4. When the value of μ is larger (i.e. $\mu = 2$), the bank is always able to issue CoCo bonds. However, in accordance with Proposition 2, we notice that when r_2^* exists, it is a decreasing function in K_0. Weakly-capitalized banks find therefore it more costly to issue CoCo bonds than better-capitalized banks.

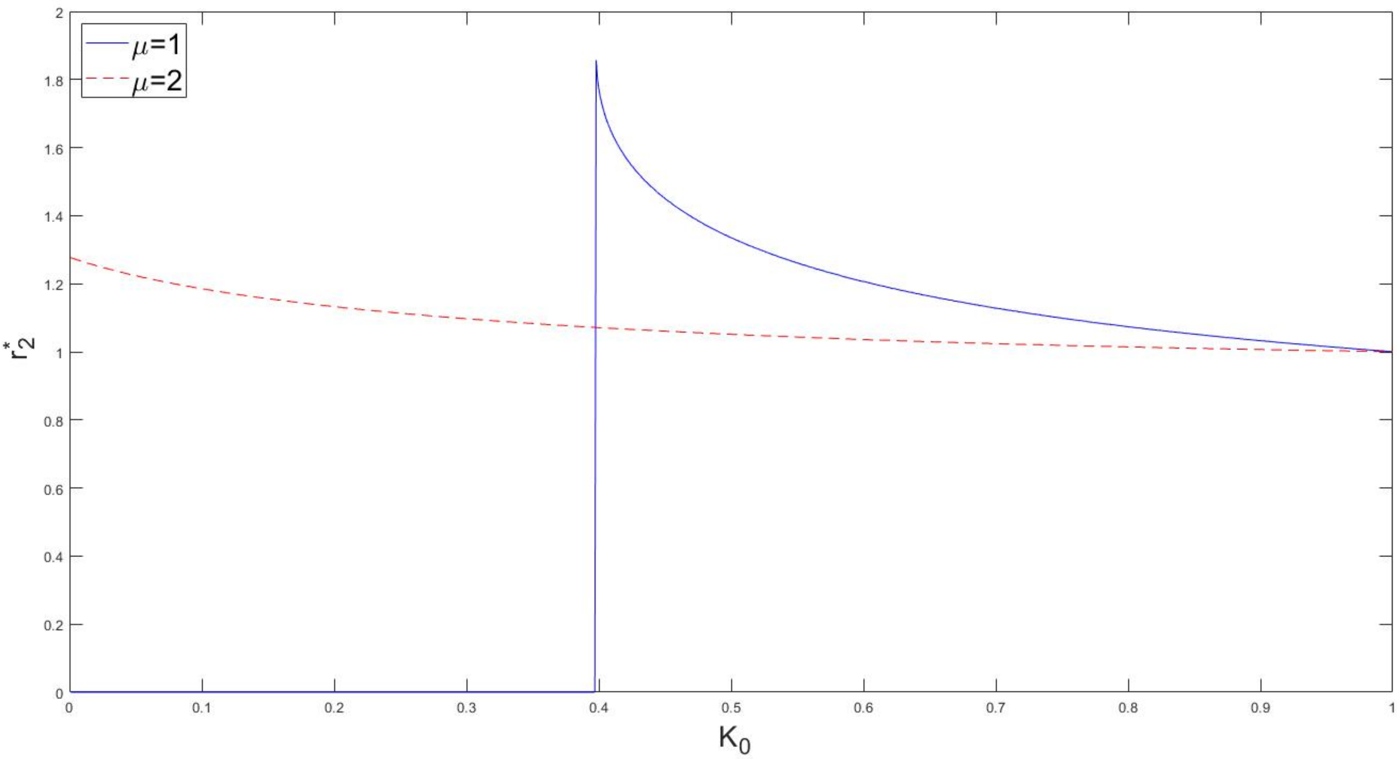

Figure 2: The equilibrium return r_2^* as a function of K_0 for some values of μ

4 Optimal proportion of CoCo bonds

4.1 Regular bonds and CoCo bonds

We assume here that the bank resorts to both CoCo bonds and regular bonds. CoCo bonds are once again associated with a capital trigger. We assume that regular bonds are always bailed-out. In this case, the return associated with regular bonds is the riskless return, which is equal to 1. We are looking for the optimal combination between CoCo bonds and regular bonds. The optimal proportion of CoCo bonds is defined as the one that minimizes the loss function presented below. Let us denote by y_1 the proportion of regular bonds and by y_2 the proportion of CoCo bonds. Recall that CoCo bonds are written off whenever the $t = 1$ capital of the bank is below 0:

$$\theta - y_1 - y_2 r_2 \leq 0 \iff \theta \leq \bar{\theta} \equiv 1 - K_0 + y_2(r_2 - 1). \tag{5}$$

4.2 Loss analysis

To determine the optimal proportion of CoCo bonds the bank should hold, we resort to a loss analysis. We define the following loss function:

$$\begin{aligned} L &= \chi F_t(\underline{\theta}) y_1 + (1-\chi)[1 - F_t(\bar{\theta})](r_2 - 1) y_2 \\ &= \chi F_t(\underline{\theta})(1 - K_0 - y_2) + (1-\chi)[1 - F_t(\bar{\theta})](r_2 - 1) y_2, \end{aligned} \tag{6}$$

where $\underline{\theta}$ is the value of θ below which the bank ends up insolvent even if CoCo bonds are written off:

$$\theta - y_1 \leq 0 \iff \theta \leq \underline{\theta} \equiv 1 - K_0 - y_2. \tag{7}$$

$\chi \in [0, 1]$ accounts for the weight granted to the loss supported by the government and the taxpayers in the case where a bailout occurs. This loss consists in the probability that the bank ends up insolvent (i.e. $F\left(\underline{\theta}\right)$) times the amount of regular bonds that have to be bailed-out (i.e. y_1). $1 - \chi$ is the weight associated with the loss supported by the bank. This loss consists in the risk premium (i.e. $r_2 - 1$) the bank has to pay on CoCo bonds when those are not converted, which occurs with probability $1 - F(\bar{\theta})$. CoCo bonds work in a way as a private insurance the bank buys to cover itself against the possibility of bankruptcy. The loss supported by the bank is therefore the premium it has to pay on

CoCo bonds to get insured against bankruptcy. If CoCo bonds are written off, the loss is supported by those who have decided to buy them in the first place. This potential loss is already taken into account in the pricing of CoCo bonds. An increase in CoCo bonds holding (i.e. an increase in y_2) has *a priori* several implications on the loss function:

- it reduces the loss supported by the government and the taxpayers since it decreases both the cost (y_1 decreases when y_2 increases) and the probability of a bailout ($\underline{\theta}$ is indeed decreasing in y_2),
- it increases the probability for CoCo bonds to be written off (since $\bar{\theta}$ is increasing in y_2) thus it increases the cost of CoCo bonds (r_2^* if it exists). The risk premium the bank has to pay on CoCo bonds therefore increases when y_2 increases.

We want to compute the optimal proportion of CoCo bonds. Let us denote this proportion by y_2^*. We define y_2^* as the solution of the following program:

$$\begin{aligned} &\min_{y_2} L = \chi F_t(\underline{\theta})(1-K_0-y_2) + (1-\chi)[1-F_t(\bar{\theta})](r_2-1)y_2 \\ \text{s.t.} \quad & r_2^* \text{ exists.} \end{aligned} \tag{8}$$

Recall that r_2^* exists whenever the following equation admits a solution:

$$\left[1 - F_t\left(\bar{\theta}\right)\right] r_2 = 1. \tag{9}$$

Proposition 3. *When $\chi = 1$, the optimal proportion of CoCo bonds is equal to the maximum value of y_2, the first-best value of y_2 is therefore $1 - K_0$.*

Proof. When $\chi = 1$, $L = 0$ when $y_2 = 1-K_0$. The loss function thus reaches its minimum value when $y_2 = 1 - K_0$. □

When the loss function only takes the loss supported by the taxpayers into account (i.e. when $\chi = 1$), y_2 should be the largest possible. In that case, we get $L = 0$ and the first-best equilibrium is reached. However, this equilibrium cannot always be reached because there does not necessarily exist an equilibrium value of r_2 for such a value of y_2 (see Proposition 1). Precisely, if the bank is not sufficiently capitalized and/or the expected return associated with the asset portfolio is too low, there is no equilibrium value of r_2 for the first-best value of y_2^*.

Figure 3 plots y_2^* as a function of χ for some values of K_0 and r_2^* as a function of y_2 for some values of K_0. We assume that $r_2^* = 0.5$ when there is no equilibrium value of r_2 (in the sense of Proposition 1) and that $r_2^* = 0$ for impossible values of y_2. Recall that the balance sheet identity requires that $K_0 + y_1 + y_2 = 1$. Since K_0 is exogenous, the theoretical maximum value of y_2 is reached when $y_1 = 0$. In this case we have $y_2 = 1 - K_0$. Values of y_2 greater than $1 - K_0$ are therefore impossible values. We first notice that the optimal proportion of CoCo bonds is always equal to 0 when χ is smaller than a certain threshold that depends on the value of the parameters. In other words, when the loss supported by the government and the taxpayers weighs less than a certain value, the optimal proportion of CoCo bonds is equal to 0. On the contrary, when the taxpayers' interest is taken into consideration – i.e. for larger values of χ – the optimal proportion of CoCo bonds becomes positive. y_2^* is thus as expected an increasing function in χ. Surprisingly, we notice that y_2^* is larger when $K_0 = 0.5$ than when $K_0 = 0.1$ for values of χ above approximately 0.75. The reason why is twofold. First, when the bank is weakly-capitalized (i.e. $K_0 = 0.1$), issuing CoCo bonds is very costly as can be seen in the right plot in Figure 3. The risk premium associated with CoCo bonds is therefore very high and so is the loss supported by the bank. Second, when $K_0 = 0.1$, there is a range of values of y_2 for which no equilibrium value of r_2 can be found. For instance, when $\chi = 1$, the optimal value of y_2 should be equal to its maximum value, i.e. $1 - K_0$ (Proposition 3). However, when $K_0 = 0.1$, r_2^* does not exist for y_2 greater than approximately 0.4. 0.4 is therefore the maximum value of y_2^* when $K_0 = 0.1$, while the value of y_2^* would have been $1 - K_0 = 0.9$ if the first-best equilibrium had been reached. On the contrary, when $K_0 = 0.5$, y_2^* is equal to its theoretical maximum when $\chi = 1$. In this case, we have $y_2^* = 0.5$ which is indeed the theoretical maximum value of y_2^* when $K_0 = 0.5$. The first-best equilibrium is thus reached only when $K_0 = 0.5$.

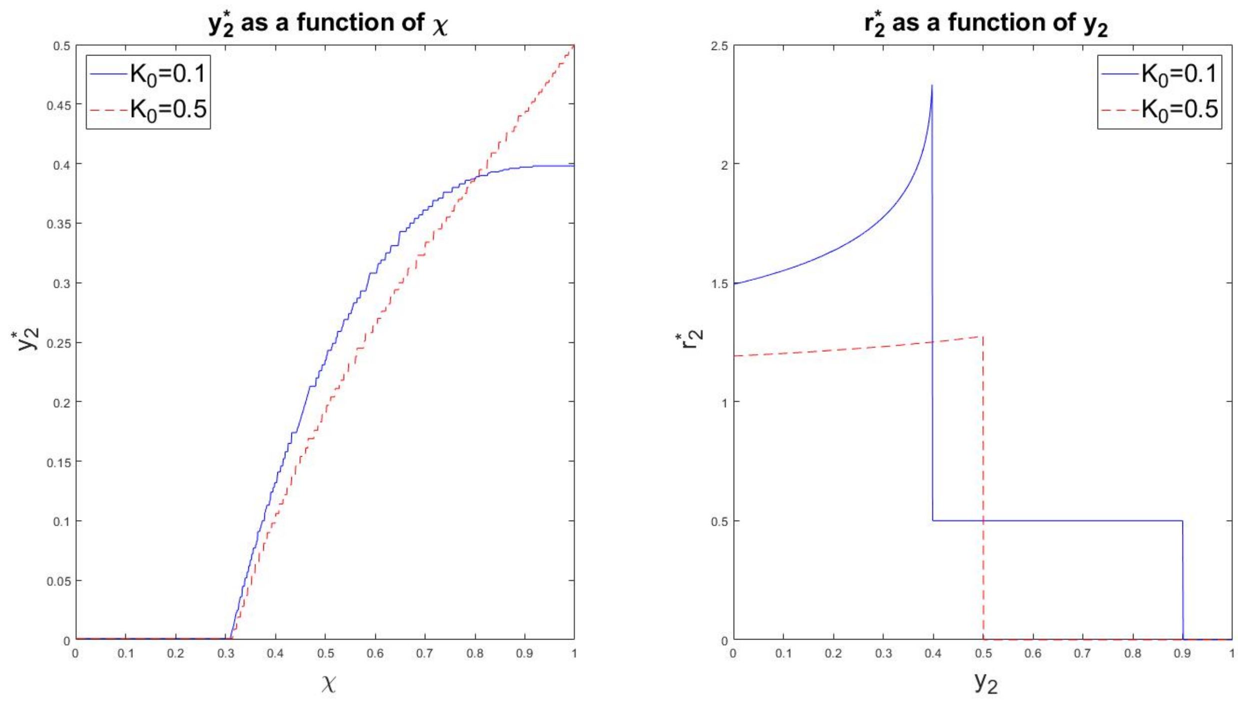

Figure 3: The optimal proportion of CoCo bonds ($\mu = 1.1$, $\sigma^2 = 1$)

Now that we have computed the optimal proportion of CoCo bonds the bank should hold, we can compute the minimum loss function for different values of the parameters to assess the efficiency of CoCo bonds in reducing the total loss. We define the minimum loss function as follows:

$$L_{\min} = \chi F(\underline{\theta})(1 - K_0 - y_2^*) + (1 - \chi)[1 - F(\bar{\theta})](r_2^* - 1)y_2^*. \tag{10}$$

$L_{\min}$ is therefore the value of the loss function when the proportion of CoCo bonds is optimal. Figure 4 plots $L_{\min}$ as a function of χ for some values of K_0. We first notice that the loss is a decreasing function in K_0: no matter the value of χ, the total loss is smaller when the bank is better capitalized. When $\chi = 0$ – i.e. when the loss supported by the government and the taxpayers is not taken into consideration in the loss function – the loss is always equal to 0. In this case, the bank does not hold any CoCo bond (see Figure 3) and consequently does not have to pay any risk premium. When $\chi = 1$, we observe that the total loss is equal to 0 only when $K_0 = 0.5$. When $K_0 = 0.1$ the total loss remains large when $\chi = 1$. The reason why is that in that case the first-best equilibrium cannot be reached because there is no equilibrium value of r_2 for the first-best value of y_2.

When the bank is well-capitalized, the minimum loss function is almost symmetrical with its lowest values lying close to $\chi = 0$ and $\chi = 1$. In that case, CoCo bonds help reducing efficiently the loss depending on the preference of the social planner (i.e. depending on the value of χ). On the contrary, when $K_0 = 0.1$, the minimum loss function is far from being symmetrical. In that case, if the social planner cares about the interest of the taxpayers, he cannot efficiently reduce the loss resorting solely to CoCo bonds. CoCo bonds are therefore not a panacea when banks are initially not capitalized enough. Banks need first to be well-capitalized and then only CoCo bonds can be used as additional instruments to strengthen these banks' soundness. Assuming that the social planner cares more about taxpayers (i.e. χ is above 0.5) and that the bank is initially weakly-capitalized (i.e. $K_0 = 0.1$), he would indeed optimally first increase equity requirements to make the bank switch from the continuous curve to the dotted curve and then only CoCo bonds could be used to lower efficiently the total loss. CoCo bonds are therefore to be thought of as a complement to equity and not as a substitute. Weakly-capitalized banks cannot indeed take full advantage of CoCo bonds since they either have to pay high premia on CoCo bonds or are not able to issue enough CoCo bonds at all.

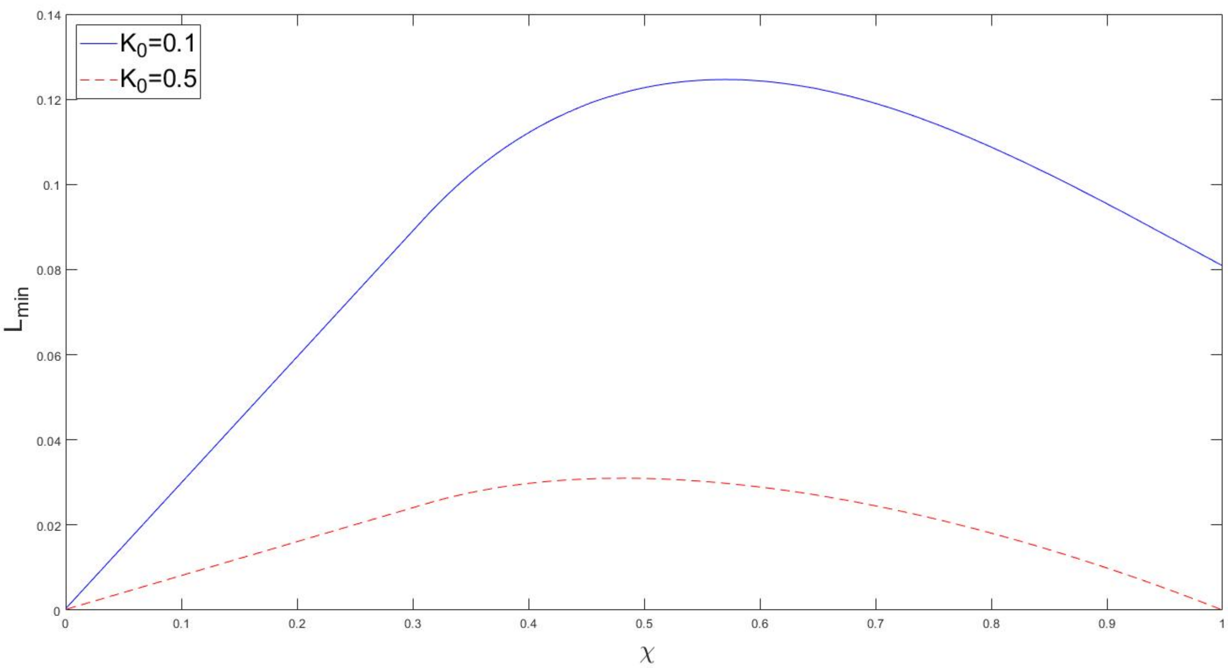

Figure 4: The minimum loss function as a function of χ for some values of K_0 ($\mu = 1.1$, $\sigma^2 = 1$)

5 Panic in the CoCo bonds' market

5.1 General setup

We introduce here the possibility for CoCo bonds' holders to sell their CoCo bonds between $t = 0$ and $t = 1$. The rest of the model remains the same. We assume that the bank relies only on CoCo bonds and on equity. y is therefore entirely made of CoCo bonds whose return, when it exists, is denoted by r_2^*. We assume that CoCo bonds can be sold at a price:

$$p(r_2^*) = \delta r_2^*, \tag{11}$$

where $\delta \in [0, 1]$ is a parameter that accounts for the liquidity risk associated with CoCo bonds. CoCo bonds' holders do not know the true distribution of θ. They are granted a public signal through the financial statements of the bank that allows them to know that θ is normally distributed with mean μ and variance $\frac{1}{\alpha}$. α is thus the precision of the information disclosed by the bank: an increase in α – because of regulatory requirements such as the third pillar of Basel III – consists in an increase in the precision of the public signal. The public signal is common knowledge to all CoCo bonds' holders. Each investor also has its own assessment of the financial situation of the bank. This assessment is summarized in a private signal $v_i = \theta + \varepsilon_i$ with $\varepsilon_i \hookrightarrow \mathcal{N}(0, \frac{1}{\beta})$. β is here the precision of the private signal. When β is large, i.e. when private signals are very accurate, investors are sophisticated in the sense that they are able to assess precisely the financial situation of the bank on their own. We assume that the noises associated with the private signals are independent of each other (i.e. $\mathbb{E}(\varepsilon_i \varepsilon_j) = 0$ for $i \neq j$) and of θ (i.e. $\mathbb{E}(\varepsilon_i \theta) = 0$). We assume a continuum of risk-neutral CoCo bonds' holders. CoCo bonds' holders are incentivized to sell their CoCo bonds if they expect that they are likely to be written off. We assume here that CoCo bonds are associated with both a mechanical and a discretionary trigger, which is often the case in reality.[2] The mechanical trigger is the same as the one that has been presented in the previous sections. Recall that CoCo bonds are mechanically written off whenever the return θ of the asset portfolio is below a threshold defined as follows:

$$\theta \leq \theta^* \equiv (1 - K_0) r_2. \tag{12}$$

[2]For instance, according to CRD IV, to be considered as regulatory capital, CoCo bonds need to be associated with both a mechanical and a discretionary trigger.

CoCo bonds can also be discretionarily written off if the regulatory institution in charge of the bank – let us call it the Central Bank – decides to trigger the conversion. The Central Bank can therefore force the conversion of CoCo bonds even when the mechanical threshold described in (12) is not crossed. Precisely, we assume that the Central Bank follows two objectives. A microprudential objective, which consists in converting CoCo bonds when the bank faces difficulties in order to make it possible for it to continue its activities as a going-concern, and a macroprudential objective, which consists in preventing systemic risk from materializing. To take those two objectives into account, we assume that the Central Bank decides to write CoCo bonds off when the capital of the bank falls below a certain threshold (microprudential objective) and/or when the amount of CoCo bonds that are being sold is such that those sales could have a destabilizing impact on the functioning of the financial system as a whole (macroprudential objective). We therefore define the discretionary threshold as follows:

$$\begin{aligned} & \theta - yr_2 \leq sy \\ \iff \quad & \theta \leq \theta^{**} \equiv (1 - K_0)(r_2 + s), \end{aligned} \tag{13}$$

where $s \in [0, 1]$ is a variable that accounts for the proportion of CoCo bonds' holders that decide to sell their CoCo bonds between $t = 0$ and $t = 1$. ys is thus the proportion of the CoCo bonds issued by the bank that is sold between $t = 0$ and $t = 1$. In other words, we assume that the Central Bank monitors the CoCo bonds' market and is more likely to trigger their conversion when sales increase. The discretionary trigger is in fact a capital trigger that takes the proportion of CoCo bonds that are being sold into account. The conversion is indeed triggered whenever the $t = 1$ capital of the bank (i.e. $\theta - yr_2$) is below the proportion of CoCo bonds that are being sold (i.e. sy). We notice that the probability for CoCo bonds to be discretionarily written off is an increasing function in the proportion s of CoCo bonds' holders that decide to sell. According to (13), θ^{**} is indeed an increasing function in s. In other words, when s increases, CoCo bonds are more likely to be written off and creditors are thus more inclined to sell them. In this sense, selling decisions are strategic complements since creditor i is more incentivized to sell if creditor j does so and *vice versa*. This is in line with the empirical evidence provided by Bologna *et al.* (2018) according to which CoCo bonds markets are subject to self-fulfilling behaviors.

5.2 Pricing

For simplicity we assume that only the mechanical conversion risk is taken into consideration while pricing CoCo bonds. In reality, CoCo bonds associated with both a mechanical trigger and a discretionary trigger are likely to be priced this way since it is *ex ante* virtually impossible to assess the probability of a discretionary conversion. In addition, we assume here that θ is normally distributed with mean μ and variance σ^2. The normal distribution is a less credible assumption than the left-truncated normal distribution used in section 3.2, but it will prove more convenient to solve the game without altering the main characteristics of the equilibrium return. It is indeed easy to show that Proposition 1 holds when θ is normally distributed and thus that the equilibrium return behaves qualitatively the same whether θ is normally or truncated-normally distributed. As shown in Figure 5, the main difference between the two distributions is that the normal distribution yields an upward biased price since it overstates the probability of conversion.

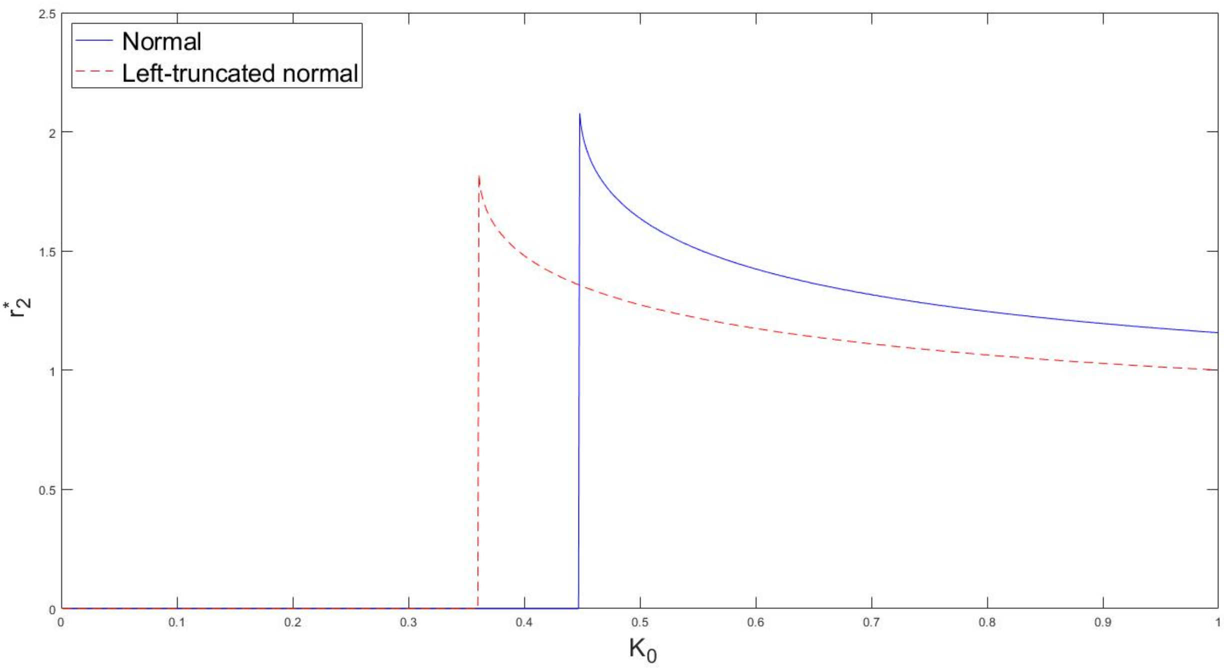

Figure 5: r_2^* when θ is normally distributed and truncated-normally distributed ($\mu = 1.1$, $\sigma^2 = 1$)

5.3 Global game

CoCo bonds' holders decide to sell when they expect CoCo bonds to be written off. Since they do not know the true distribution of θ, CoCo bonds' holders can only base their estimation of the probability of conversion on the noisy information they possess. Precisely creditor i decides to sell its CoCo bonds whenever the probability that CoCo bonds are not written off times the return associated with CoCo bonds is smaller than their market price. That is when the following inequality holds true:

$$\underbrace{\Pr\left[\{\, \theta \geq \theta^{*} \,\} \cup \{\, \theta \geq \theta^{**} \,\} | \mu, v_i\right]}_{\text{Probability of no conversion conditional on the signals}} \qquad r_2^* \leq \delta r_2^*. \tag{14}$$

According to (12) and (13), we know for sure that $\theta^{**} \geq \theta^{*}$, which is in line with the way regulatory CoCo bonds have been designed.[3] (14) can therefore be rewritten as follows:

$$\Pr\left[\theta \geq \theta^{**} | \mu, v_i\right] \leq \delta. \tag{15}$$

As we assumed that the noise parameters ε_i are normally distributed, we know that the distribution of θ conditional on μ and v_i is normal as well. The expected value of θ conditional on μ and v_i is thus:

$$\mathbb{E}[\theta | \mu, v_i] = \frac{\alpha\mu + \beta v_i}{\alpha + \beta}, \tag{16}$$

and its variance is

$$\mathrm{Var}[\theta | \mu, v_i] = \frac{1}{\alpha + \beta}. \tag{17}$$

We can therefore rewrite (15) as follows:

$$1 - \Phi\left[\sqrt{\alpha + \beta}\left(\theta^{**} - \frac{\alpha\mu + \beta v_i}{\alpha + \beta}\right)\right] \leq \delta, \tag{18}$$

where $\Phi(\cdot)$ is the cumulative distribution function of the standard normal distribution. CoCo bonds' holders are thus indifferent between selling or holding their CoCo bonds

[3] In CRD IV, the mechanical trigger is set at 5.125% of the RWA, which is far below the capital level of banks that have been bailed-out during the crisis. If they were to happen, conversions of regulatory CoCo bonds would therefore likely be discretionary instead of mechanical (Cahn and Kenadjian, 2014).

when:

$$\begin{aligned} & 1-\Phi\left[\sqrt{\alpha+\beta}\left(\theta^{**}-\tfrac{\alpha\mu+\beta v_i}{\alpha+\beta}\right)\right]=\delta \\ \Longleftrightarrow \quad & v_{Cr}^*=\tfrac{\alpha+\beta}{\beta}\theta^{**}-\tfrac{\sqrt{\alpha+\beta}}{\beta}\Phi^{-1}(1-\delta)-\tfrac{\alpha\mu}{\beta}. \end{aligned} \tag{19}$$

v_{Cr}^* is therefore the threshold value of the private signal below which creditors decide to sell their CoCo bonds. A creditor i that would observe a private signal v_i below v_{Cr}^* would sell its CoCo bonds while it would hold them otherwise. According to (13), the Central Bank forces the conversion of CoCo bonds whenever the following inequality holds true:

$$\theta \leq \theta^{**} \equiv (1-K_0)(r_2^*+s). \tag{20}$$

We assume that creditors follow a threshold strategy, meaning that each creditor i decides to sell when the private signal v_i he observes is smaller than or equal to a threshold v^*, given θ. Since ε_i is independent of ε_j and of θ, we know that s is given by the probability with which a creditor i observes a private signal below v^*:

$$s=\Pr\left[v_i \leq v^*|\theta\right]=\Phi\left(\sqrt{\beta}(v^*-\theta)\right). \tag{21}$$

Combining (20) and (21), we can derive the indifference curve of the Central Bank:

$$\begin{aligned} & \theta=(1-K_0)\left[r_2^*+\Phi\left(\sqrt{\beta}(v^*-\theta)\right)\right] \\ \Longleftrightarrow \quad & v_{CB}^*=\tfrac{1}{\sqrt{\beta}}\Phi^{-1}\left[\tfrac{\theta}{1-K_0}-r_2^*\right]+\theta. \end{aligned} \tag{22}$$

Equations (19) and (22) allow us to find the equilibrium value of θ:

$$\begin{aligned} & \tfrac{1}{\sqrt{\beta}}\Phi^{-1}\left[\tfrac{\theta_e}{1-K_0}-r_2^*\right]+\theta_e=\tfrac{\alpha+\beta}{\beta}\theta_e-\tfrac{\sqrt{\alpha+\beta}}{\beta}\Phi^{-1}(1-\delta)-\tfrac{\alpha\mu}{\beta} \\ \Longleftrightarrow \quad & \theta_e=(1-K_0)\left(r_2^*+\Phi\left[\tfrac{\alpha}{\sqrt{\beta}}\left(\theta_e-\mu-\tfrac{\sqrt{\alpha+\beta}}{\alpha}\Phi^{-1}(1-\delta)\right)\right]\right). \end{aligned} \tag{23}$$

Proposition 4. *Provided that $\beta > \frac{\alpha^2}{2\pi}$ (sufficient condition), there exists a unique equilibrium value of θ that satisfies* (23)*.*

Proof. For the equilibrium value of θ to be unique, v_{Cr}^* and v_{CB}^* need to cross only once. This is the case if $\frac{\partial v_{CB}^*}{\partial\theta} > \frac{\partial v_{Cr}^*}{\partial\theta}$ for all θ. We have:

$$\begin{aligned} \frac{\partial v_{CB}^*}{\partial\theta} &= \frac{1}{\sqrt{\beta}}\frac{\partial\Phi^{-1}(\cdot)}{\partial\theta}+1, \\ \frac{\partial v_{Cr}^*}{\partial\theta} &= \frac{\alpha+\beta}{\beta}. \end{aligned} \tag{24}$$

As $\min\left\{\frac{\partial\Phi^{-1}(\cdot)}{\partial\theta}\right\} = \frac{1}{\max\{\phi(\cdot)\}} = \sqrt{2\pi}$ with $\phi(\cdot)$ the probability density function of the standard normal distribution, a sufficient condition for $\frac{\partial v^*_{CB}}{\partial\theta} > \frac{\partial v^*_{Cr}}{\partial\theta}$ is $\beta > \frac{\alpha^2}{2\pi}$. □

From now on we assume that $\beta > \frac{\alpha^2}{2\pi}$, i.e. θ_e is unique. θ_e is the threshold value of θ below which CoCo bonds are both written off and sold and above which they are neither written off nor sold. When $\theta \leq \theta_e$, panic sales occur and CoCo bonds are converted. This situation is therefore referred to as a crisis or a panic: the fear that CoCo bonds could be written off and that of subsequent panic sales lead both to conversion and panic sales. An increase in the value of θ_e can thus be interpreted as an increase in the probability of crisis.

Proposition 5. *When the CoCo bonds' market becomes more liquid, a crisis is more likely to occur (i.e.* $\frac{\partial\theta_e}{\partial\delta} \geq 0$*).*

Proof. We differentiate θ_e with respect to δ:

$$\frac{\partial\theta_e}{\partial\delta} = -\frac{\left[\frac{\sqrt{\alpha+\beta}}{\sqrt{\beta}}\frac{\partial\Phi^{-1}(1-\delta)}{\partial\delta}\right](1-K_0)\phi(\cdot)}{1-(1-K_0)\frac{\alpha}{\sqrt{\beta}}\phi(\cdot)} \geq 0. \tag{25}$$

Due to the uniqueness condition (i.e. $\beta \geq \frac{\alpha^2}{2\pi}$), we know that $1-(1-K_0)\frac{\alpha}{\sqrt{\beta}}\phi(\cdot) \geq 0$. In addition, we know that $\Phi^{-1}(x)$ is an increasing function in x so $\frac{\partial\Phi^{-1}(1-\delta)}{\partial\delta} \leq 0$. Therefore $\frac{\partial\theta_e}{\partial\delta} \geq 0$. □

This result is intuitive: when CoCo bonds are liquid, it is less costly for a creditor to sell them and thus sales are more likely to occur. Consequently the Central Bank is more likely to force the conversion of CoCo bonds and a panic is more likely to occur. As capital instruments, CoCo bonds should then be associated with a liquidity risk. The maturity of CoCo bonds should therefore be long enough.

Proposition 6. *Increasing the precision of the public signal has an ambiguous impact on the probability of crisis: when* $\theta_e \leq \mu + \frac{\Phi^{-1}(1-\delta)}{2\sqrt{\alpha+\beta}}$*, we have* $\frac{\partial\theta_e}{\partial\alpha} \leq 0$ *while* $\frac{\partial\theta_e}{\partial\alpha} > 0$ *when* $\theta_e > \mu + \frac{\Phi^{-1}(1-\delta)}{2\sqrt{\alpha+\beta}}$.

Proof. We differentiate θ_e with respect to α:

$$\frac{\partial\theta_e}{\partial\alpha} = \frac{\frac{1-K_0}{\sqrt{\beta}}\left[\theta_e-\mu-\frac{\Phi^{-1}(1-\delta)}{2\sqrt{\alpha+\beta}}\right]\phi(\cdot)}{1-(1-K_0)\frac{\alpha}{\sqrt{\beta}}\phi(\cdot)}. \tag{26}$$

If $\theta_e \leq \mu + \frac{\Phi^{-1}(1-\delta)}{2\sqrt{\alpha+\beta}}$, we have $\frac{\partial\theta_e}{\partial\alpha} \leq 0$. On the contrary, if $\theta_e > \mu + \frac{\Phi^{-1}(1-\delta)}{2\sqrt{\alpha+\beta}}$, we have $\frac{\partial\theta_e}{\partial\alpha} > 0$. □

When the probability of crisis is already high – i.e. when $\theta_e > \mu + \frac{\Phi^{-1}(1-\delta)}{2\sqrt{\alpha+\beta}}$ – increasing the transparency of the information disclosed by the financial statements increases the probability of crisis. In this case, if the regulator wants to avoid panic sales some opacity should be permitted. On the contrary, when the probability of crisis is initially low – i.e. when $\theta_e \leq \mu + \frac{\Phi^{-1}(1-\delta)}{2\sqrt{\alpha+\beta}}$ – increasing the precision of the public signal decreases that probability.

Proposition 7. *An increase in the expected return associated with the asset portfolio decreases the probability of crisis, i.e.* $\frac{\partial\theta_e}{\partial\mu} \leq 0$.

Proof. We differentiate θ_e with respect to μ:

$$\frac{\partial\theta_e}{\partial\mu} = -\frac{(1-K_0)\frac{\alpha}{\sqrt{\beta}}\phi(\cdot)}{1-(1-K_0)\frac{\alpha}{\sqrt{\beta}}\phi(\cdot)} \leq 0. \tag{27}$$

□

The impact of an increase in the precision of the public signal on the probability of crisis depends on the threshold value θ_e (Proposition 6). Since θ_e is a decreasing function in μ (Proposition 7), the sign of $\frac{\partial\theta_e}{\partial\alpha}$ also depends on μ. Precisely there should exist a value of μ, denoted μ_α, such that $\frac{\partial\theta_e}{\partial\alpha} \geq 0$ when $\mu \leq \mu_\alpha$ and $\frac{\partial\theta_e}{\partial\alpha} < 0$ otherwise.

Proposition 8. *Increasing the precision of the private signal has an ambiguous impact on the probability of crisis: when* $\theta_e \leq \mu + \frac{\Phi^{-1}(1-\delta)}{\sqrt{\alpha+\beta}}$, *we have* $\frac{\partial\theta_e}{\partial\beta} \geq 0$ *while* $\frac{\partial\theta_e}{\partial\beta} < 0$ *when* $\theta_e > \mu + \frac{\Phi^{-1}(1-\delta)}{\sqrt{\alpha+\beta}}$.

Proof. We differentiate θ_e with respect to β:

$$\frac{\partial\theta_e}{\partial\beta} = \frac{\frac{(1-K_0)\alpha}{2\beta\sqrt{\beta}}\left[-\theta_e + \mu + \frac{1}{\sqrt{\alpha+\beta}}\Phi^{-1}(1-\delta)\right]\phi(\cdot)}{1-(1-K_0)\frac{\alpha}{\sqrt{\beta}}\phi(\cdot)}. \tag{28}$$

If $\theta_e \leq \mu + \frac{\Phi^{-1}(1-\delta)}{\sqrt{\alpha+\beta}}$, we have $\frac{\partial\theta_e}{\partial\beta} \geq 0$. On the contrary, if $\theta_e > \mu + \frac{\Phi^{-1}(1-\delta)}{\sqrt{\alpha+\beta}}$, we have $\frac{\partial\theta_e}{\partial\beta} < 0$. □

We notice that the impact of an increase in the private signal on the probability of crisis depends on the threshold value θ_e. For an initially high value of θ_e (i.e. high probability of crisis), an increase in the precision of the private signal decreases the probability of crisis while it has the opposite effect for an initially low probability of crisis. As before, since θ_e is a decreasing function in μ, we can find a value of μ, denoted μ_β, such that $\frac{\partial\theta_e}{\partial\beta} \leq 0$ when $\mu \leq \mu_\beta$ and $\frac{\partial\theta_e}{\partial\beta} > 0$ otherwise. Table 4 summarizes the results presented in Propositions 6 and 8.

$\mu \leq \mu_\beta$	$\mu \in]\mu_\beta; \mu_\alpha]$	$\mu_\alpha < \mu$
$\frac{\partial\theta_e}{\partial\alpha} \geq 0$	$\frac{\partial\theta_e}{\partial\alpha} \geq 0$	$\frac{\partial\theta_e}{\partial\alpha} < 0$
$\frac{\partial\theta_e}{\partial\beta} \leq 0$	$\frac{\partial\theta_e}{\partial\beta} > 0$	$\frac{\partial\theta_e}{\partial\beta} > 0$

Table 1: Precision of information and risk of crisis

Depending on the expected return associated with the asset portfolio, the impact of an increase in the precision of the information is not the same. In particular the nature of the information has to be taken into consideration. When the expected return of the asset portfolio is large enough, increasing the precision of the public signal decreases the probability of crisis while an increase in the precision of the private signal has the opposite effect. We showed (Proposition 1) that the bank is only able to issue CoCo bonds when the expected return associated with the asset portfolio is high enough. Therefore it is likely that for the range of values of μ for which the bank can issue CoCo bonds we have $\frac{\partial\theta_e}{\partial\alpha} < 0$ and $\frac{\partial\theta_e}{\partial\beta} > 0$. Figure 6 indeed shows that when the precision of the public signal increases (left plot), the value of θ_e decreases for all possible values of μ (i.e. values of μ above the threshold value of approximately 1.8 below which no CoCo can be issued). On the contrary, when the precision of the private signal increases (right plot), θ_e increases and so does the probability of crisis. Results are qualitatively the same for a better-capitalized bank (see Figure 7 where $K_0 = 0.5$). It is therefore preferable for the public information to be as precise as possible while the private information should remain relatively noisy (as far as the uniqueness condition presented in Proposition 4 holds true). Concretely, on the one hand, regulatory disclosure requirements should be implemented as far as CoCo bonds are concerned to make sure that public information is as precise as possible. On the other hand, CoCo bonds should not be sold to very sophisticated investors that possess precise private information on the bank – such as hedge funds – since those could potentially have a destabilizing impact on the market.

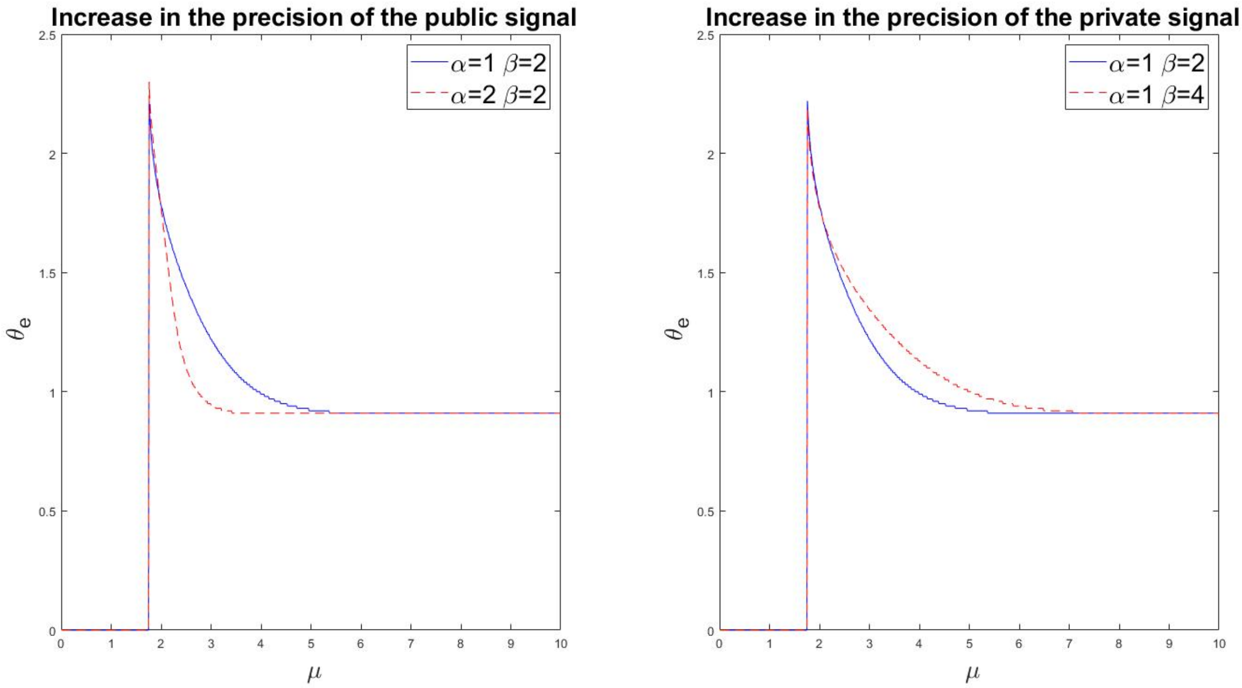

Figure 6: The impact of an increase in the precision of information ($\delta = 0.75$ and $K_0 = 0.1$)

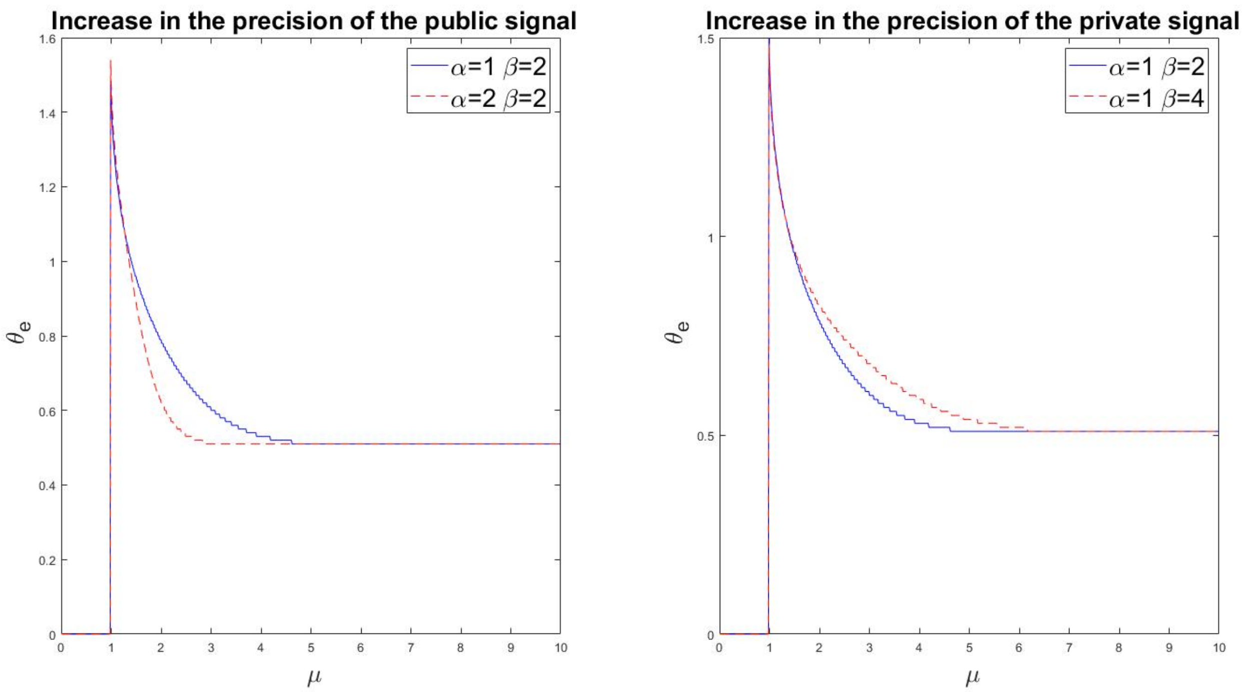

Figure 7: The impact of an increase in the precision of information ($\delta = 0.75$ and $K_0 = 0.5$)

6 Discussion and policy implications

After the crisis, banking regulation has narrowed the definition of regulatory capital. Under Basel III, banks are indeed constrained to hold 4.5% of their risk-weighted assets (RWA) in core capital (CET1), which is more than twice the constraint under Basel II. In addition, counter-cyclical buffers have been added to the main framework and raised to 7% of the RWA the constraint in capital CET1. Simultaneously, Basel III allows a certain proportion of the capital CET1 to be made of CoCo bonds.[4] To be included in regulatory capital, CoCo bonds have however to be designed in a specific way. According to CRD IV – the European transposition of the Basel III framework – regulatory CoCo bonds have indeed to be associated with both a discretionary and a mechanical trigger and the latter has to be capital-based with a threshold greater than or equal to 5.125% of the RWA.

Our model allows us to discuss the way CoCo bonds have been treated by the regulation. We think that our results raise at least two criticisms that can be addressed to current regulatory CoCo bonds. First, we think that regulatory CoCo bonds are seen less as a complement to equity than as an imperfect substitute by current regulatory requirements. Indeed even if equity requirements have been raised, they still remain far under the level suggested by Admati *et al.* (2013) and maybe also under the level beyond which CoCo bonds could perform efficiently according to our model. We therefore call for a sharp increase in equity requirements as a prerequisite for any form of CoCo bonds requirement. The second and maybe the main concern is that it seems there is no clear answer to the question of the identity of ideal CoCo bonds' buyers. In a macroprudential perspective, it does not make sense for banks to buy other banks' CoCo bonds since this would only consist in building new transmission channels that could eventually prove a great factor of systemic risk. Retail customers are not sophisticated enough and therefore have to be prevented from investing in CoCo bonds. Persaud (2014) strongly objects the idea according to which long-term investors should invest in CoCo bonds. He argues that this would go against their business model and thus could be detrimental to the funding of long-term investments. Hedge funds remain potential investors. However, we showed in the previous section that when the private information available to CoCo bonds' holders is very precise, the probability of a crisis happening increases. As well-informed traders,

[4] Precisely 1.5% of the RWA.

hedge funds could therefore be a potential factor of instability in the CoCo bonds' market.

It is therefore not clear whether or not CoCo bonds could possibly fulfill their objective of stabilizing the banking sector. In at least two respects, they appear as a fantastic transmission channel of systemic risk. On the one hand, if banks invest in other banks' CoCo bonds, conversions would automatically propagate a crisis from the defaulting bank to the rest of the banking sector. On the other hand, short-term buying/selling behaviors from sophisticated traders such as hedge funds could be a great factor of instability that could eventually lead to a crisis. It is therefore of the utmost importance to cautiously take the potential destabilizing effects of CoCo bonds into account before considering going further in the direction of regulatory requirements in CoCo bonds.

To summarize, our results make it possible to picture how regulatory CoCo bonds should be implemented if they are to be. First, there has to be a sharp increase in equity requirements before any implementation of CoCo bonds requirements. Second, the implementation of CoCo bonds requirements should be associated with regulatory disclosure requirements meant to ensure that the information common to all CoCo bonds' holders – what is referred to in our model as the public signal – is as precise as possible. Third, CoCo bonds should preferably be sold to financial institutions that are not too sophisticated – i.e. investors whose private signal is not too precise – to prevent destabilizing sales from occurring.

7 Conclusion

We develop a model where a bank relies on three funding sources: equity, regular bonds and CoCo bonds. Because of the conversion risk, pricing CoCo bonds is a tricky exercise. We indeed show that there does not necessarily exist an equilibrium return for CoCo bonds and therefore the bank is not always able to issue CoCo bonds. In particular, when the bank is too weakly capitalized and/or when the expected return associated with the asset portfolio of the bank is too low, no equilibrium price for CoCo bonds can be found. When such a price exists, it is a decreasing function in the level of capital held by the bank. In other words, the more capitalized the bank is, the easier it is to issue CoCo bonds. CoCo bonds are therefore at most to be thought of as a complement to equity but cannot efficiently serve as a substitute. The loss analysis presented in section 4 indeed shows that when the bank is weakly capitalized, it is not possible to reduce efficiently the loss solely through CoCo bonds. For instance, if the social planner only cares about taxpayers, he would be better off increasing first equity requirements and then only implementing CoCo bonds requirements. Weakly-capitalized banks cannot indeed take full advantage of CoCo bonds either because they are too expensive or because they cannot be issued.

In section 5, we explore how the conversion risk associated with CoCo bonds gives rise to self-fulfilling behaviors that can lead to panics. In particular, we show under which circumstances a crisis occurs because of the interaction between the expectation of conversion by creditors and the expectation of panic sales by the Central Bank. Since panic sales are motivated by the risk of conversion and since discretionary conversions are partly motivated by the fear of panic sales, self-fulfilling crises can occur. Using the global game technique, we show that the probability of crisis can be expressed as a function of the return associated with the asset portfolio of the bank. In addition, we show that this probability is sensitive to the precision of the information available to creditors. In particular, more accurate public information is often associated with a lower probability of crisis while on the contrary a more precise private signal increases the probability of crisis.

Those results allow us to formulate policy implications that are discussed in detail in section 6. What is worth pointing out here is the three main lessons than can be drawn out from our theoretical results. First, CoCo bonds can only act efficiently as a complement to equity and not as a substitute. Second, public information concerning CoCo bonds should be as precise as possible. Regulatory disclosure requirements should therefore be implemented as far as CoCo bonds are concerned. Third, CoCo bonds should not be sold exclusively to sophisticated investors whose behavior may prove destabilizing for the CoCo bonds' market and subsequently for the financial system as a whole.

Appendix: proof of Proposition 1

The equilibrium return of CoCo bonds is defined as the first value of r_2 that satisfies the following equality:

$$[1 - F_t(\theta^*)]\, r_2 = 1, \tag{29}$$

where $\theta^* = (1-K_0)r_2$ and $F_t(\cdot)$ is the c.d.f of the left-truncated normal distribution of θ. We denote the equilibrium value of r_2 by r_2^*. When $K_0 = 1$, we immediately have $r_2^* = 1$. Let us now define the following function:

$$g(r_2) = [1 - F_t(\theta^*)]\, r_2 - 1. \tag{30}$$

We can rewrite (30) as follows:

$$g(r_2) = 0 \iff K_0 = 1 - \frac{1}{r_2} F_t^{-1}\left(1 - \frac{1}{r_2}\right), \tag{31}$$

where $F_t^{-1}(\cdot)$ is the inverse function of $F_t(\cdot)$. For all $r_2 \in [1, +\infty[$, let us define the function $h(r_2)$ as $h(r_2) = 1 - \frac{1}{r_2} F_t^{-1}\left(1 - \frac{1}{r_2}\right)$. We notice that $\max\{h(r_2)\} = 1$. For every $K_0 \in [0, 1[$, it is therefore possible to find one r_2 such that we have $K_0 < h(r_2)$. However, for some values of μ (see Figure 8), we have $\min\{h(r_2)\} > 0$. It is therefore not possible to find one r_2 in $[1, +\infty[$ such that $K_0 \geq h(r_2)$ for every $K_0 \in [0, 1[$. In that case, there are situations where we always have $K_0 < h(r_2)$ and equation (31) does not have a solution. In other words, r_2^* does not necessarily exist.

r_2^* exists if and only if $K_0 \geq \min\{h(r_2)\}$ for $r_2 \in [1, +\infty[$. We can easily show that $F_t^{-1}(\cdot)$ is an increasing function in μ. Therefore $h(r_2)$ is a decreasing function in μ. Thus when μ increases, $\min\{h(r_2)\}$ decreases and r_2^* is more likely to exist.

To summarize, we showed that K_0 and/or μ need to be large enough for r_2^* to exist.

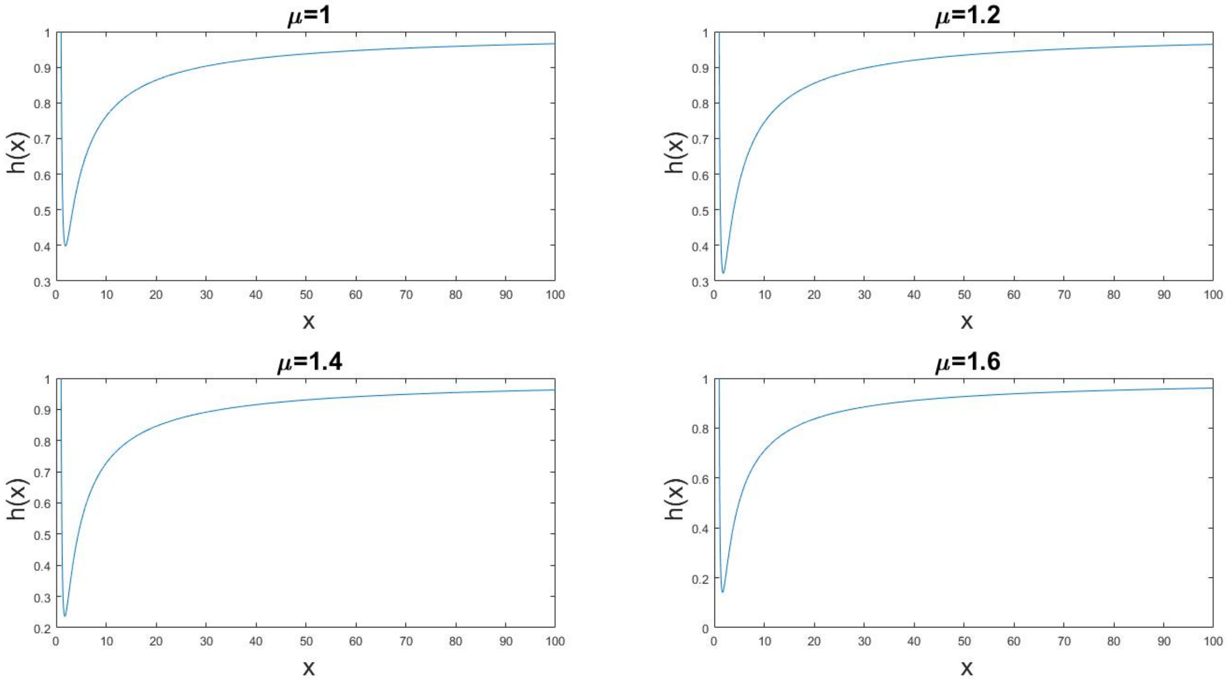

Figure 8: $h(x)$ as a function of x for some values of μ

References

[1] Admati, A. R., P. M. DeMarzo, M. F. Hellwig and P. C. Pfleiderer. 2013. Fallacies, Irrelevant Facts, and Myths in the Discussion of Capital Regulation: Why Bank Equity is Not Socially Expensive. *Max Planck Institute for Research on Collective Goods*

[2] Allen, H. J. 2012. CoCo bonds can Drive Markets Cuckoo. *Lewis & Clark Law Review* 16: 125

[3] Avdjiev, S., A. V. Kartasheva and B. Bogdanova. 2013. CoCo Bonds: A Primer. *BIS Quarterly Review*

[4] Avdjiev, S., B. Bogdanova, P. Bolton, W. Jiang and A. Kartasheva. 2017. CoCo Issuance and Bank Fragility. *BIS Working Papers*

[5] Bologna, P., A. Miglietta and A. Segura. 2018. Contagion in the CoCo Bonds Market? A Case Study of Two Stress Events. *Bank of Italy Working Paper*

[6] Cahn, A and P. Kenadjian. 2014. Contingent Convertible Securities: From Theory to CRD IV. *Goethe University Working Paper*

[7] Carlsson, H. and E. Van Damme. 1993. Global Games and Equilibrium Selection. *Econometrica* 61 (5): 989-1018

[8] Corcuera, J. M., J. De Spiegeleer, J. Fajardo, H. Jönsson, W. Schoutens and A. Valdivia. 2014. Close Form Pricing Formulas for Coupon Cancellable CoCos. *Journal of Banking and Finance* 42: 339-351

[9] Flannery, M. J. 2005. No Pain, No Gain? Effecting Market Discipline via Reverse Convertible Debentures. in H. S. Scott (ed.), *Capital Adequacy Beyond Basel: Banking, Securities, and Insurance*

[10] Flannery, M. J. 2016. Stabilizing Large Financial Institutions with Contingent Capital Certificates. *Quarterly Journal of Finance* 6: 1-26

[11] Glasserman, P. and B. Nouri. 2012. Contingent Capital with a Capital-Ratio Trigger. *Management Science* 58: 1816-1833

[12] Glasserman, P. and B. Nouri. 2016. Market-Triggered Changes in Capital Structure: Equilibrium Price Dynamics. *Econometrica* 84 (6): 2113-2153

[13] Goodhart, C. 2010. Are CoCo B from Cloud Cuckoo-Land ? VoxEU

[14] Himmelberg, C. and S. Tsyplakov. 2014. Incentive Effects and Pricing of Contingent Capital. *University of South California Working Paper*

[15] Koziol, C. and J. Lawrenz. 2012. Contingent Convertibles. Solving or Seeding the Next Banking Crisis. *Journal of Banking and Finance* 36: 90-104

[16] McDonald, R. 2013. Contingent Capital With Dual Price Trigger. *Journal of Financial Stability* 9: 230-241

[17] Metz, C. 2002. Private and Public Information in Self-fulfilling Currency Crises. *Journal of Economics* 76 (1): 65-85

[18] Morris, S. and H. S. Shin. 1998. Unique Equilibrium in a Model of Self-Fulfilling Currency Attacks. *American Economic Review* 88 (3): 587-597

[19] Morris, S. and H. S. Shin. 2003. Global Games: Theory and Applications. *Advances in Economics and Econometrics* (*Proceedings of the Eighth World Congress of the*

Econometric Society) edited by Dewatripont, M., L. Hansen and S. Turnovsky, Cambridge University Press

[20] Morris, S. and H. S. Shin. 2004. Coordination Risk and the Price of Debt. *European Economic Review* 48 (1): 133-153

[21] Pennacchi, G., T. Vermaelen, and C. Wolff. 2014. Contingent Capital: The Case of COERCs. *Journal of Financial and Quantitative Analysis* 49: 541-574

[22] Pennacchi, G. and A. Tchistyi. 2019 . On Equilibrium When Contingent Capital Has a Market Trigger: A Correction to Sundaresan and Wang *Journal of Finance* (2015). *Journal of Finance* (forthcoming)

[23] Persaud, A. 2014. *Why Bail-in Securities Are Fool's Gold*. Peterson Institute for International Economics

[24] Squam Lake Working Group. 2009. An Expedited Resolution Mechanism for Distressed Financial Firms: Regulatory Hybrid Securities. *Council on Foreign Relations, Working paper* 10

[25] Sundaresan, S. and Z. Wang. 2015. On the Design of Contingent Capital with a Market Trigger. *Journal of Finance* 70: 881-920