The Necessary Evil: Non-dilutive CoCo Bonds

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Abstract

We empirically document and investigate in a theory model why non-dilutive contingent convertible bonds (CoCos) are predominantly prevalent in the market, even though advocates of CoCos suggest such securities need to be dilutive upon conversion to dampen bank shareholders' risk-taking incentives. In an agency model with two subsequent risk-taking actions, we emphasize that the design of CoCos needs to strike a balance between mitigating ex-ante and ex-post risk-taking incentives: while dilutive CoCos can deter ex-ante risk-taking and help prevent the bank from being undercapitalized, penalizing existing shareholders with strong dilution when the bank is already undercapitalized will aggravate shareholders' incentives to gamble for resurrection. We show that the design and the efficacy of CoCos' in promoting financial stability can crucially depend on the equity capitalization of banks, with only well-capitalized banks optimally choosing to issue dilutive CoCos.

Keywords: Banking, Bank capital regulation, Contingent Convertibles

JEL classification: G21, G28

1 Introduction

Bank capital requirements constitute a cornerstone of prudential regulations, for bank capital absorbs unexpected losses for retail depositors as well as correct risk-taking incentives of bank shareholders. The scope of regulatory capital is broadened upon the introduction of the Basel III framework, with the noticeable addition of contingent convertible bonds (CoCos) to the additional Tier 1 capital (AT1) in many jurisdictions. CoCos, as a type of hybrid security, feature payoffs contingent on the adequacy of a bank's common equity capital:[1] a CoCo bond pays out like a regular bond while the bank's CET1 ratio exceeds a pre-specified threshold, but can be written off, in the case of so-called principle-write-down (PWD) CoCos, or be converted into equity at a pre-set share price, in the case of equity-conversion CoCos. The security, therefore, is 'bailed in' when a bank's common equity buffer drops and can help avoid any recapitalization by the public authorities — potentially with taxpayers' money and distorting banks' risk-taking incentives. Regulatory authorities promote CoCos as capable of overcoming banks' reluctance to re-capitalize themselves using common equity in a crisis. With the AT1 designation, CoCos quickly became a significant form of regulatory capital.[2] Over the period 2009-2020, banks outside of the US issued CoCos with a total face value of 580 billion US dollars, with global systemically important banks (G-SIBs) alone contributing to about 50% of the total amount. In the UK, for example, CoCos make about 15% of UK G-SIBs' Tier 1 capital.

While it is fair to say that the basic design of CoCos unambiguously adds to the loss-absorbing capacity of banks,[3] whether CoCos can sufficiently correct bank shareholders' risk-taking incentives heavily depends on how dilutive CoCos are when the trigger event occurs. PWD CoCos enable a net transfer from CoCo investors to banks' shareholders when the bank's CET1 ratio falls below its pre-specified threshold. The securities, arguably, would provide little incentives for bank shareholders to limit their risk-taking and avoid triggering the conversion. Yet, in the majority of cases, CoCos issued by Global Systematically Important Banks (G-SIBs) are PWD CoCos (we present the details in Panel B of Table 2). On the other hand, equity-conversion CoCos (mainly issued by British banks) can, in principle, penalize a bank's shareholders for their risk-taking by diluting their existing shares. Until recently, it was not straightforward to tell whether such equity-diversion CoCos are dilutive or not. As a consequence, it remained largely unclear to what extent those equity-conversion CoCos can correct banks' shareholders' risk-taking incentives as initial proposals suggested — until the COVID crisis and its

[1]In practice, this is measured by the Common Equity Tier 1 (CET1) ratio, which is calculated as common equity over the bank's risk-weighted assets.

[2]The main exception is the US. For CoCos have earned no particularly favorable regulatory treatment in the country, the US banks have not joined financial institutions from the rest of the world in the issuance of CoCos.

[3]The write-off of PWD CoCos deleverages the bank and reduces the default risk on the bank's senior debt. Equity-conversion CoCos, on the other hand, add to the equity buffer upon their conversion.

instantaneous (albeit relatively short-lived) aggregate negative impact on the stock market. Upon the shock, we observe that the market price of banks' common equity dropped below the pre-set conversion price for most of the banks, and yet the CET1 ratio of the banks remained far above the trigger level. In other words, in an actual banking crisis where the banks' CET1 ratios substantially decline and trigger CoCo conversion, it is hard to believe that the prevailing price of banks' common stock would be in excess of the contract-specified conversion price.[4]

Bank (parent company)	Active CoCos (equity conversion)	% as Tier 1 capital	Conversion price	Market price of bank stock (low in the COVID crisis)
HSBC	13	13.59%	£2.70 per share	£4.16 per share
Barclays	11	19.57%	£1.65 per share	£0.91 per share
Lloyds	7	17.37%	£0.63 per share	£0.31 per share
RBS	3	11.32%	£2.28 per share	£1.33 per share
Standard Chartered	4	12.80%	£5.96 per share	£4.09 per share

While CoCos may have fallen short of the original envisioning with their non-dilutive features in practice, a closer look at data also reveals that it is not entirely bad news. Examining banks' risk-taking behavior using loan-level data from syndicated loan markets, we document that banks that issued CoCos (although non-dilutive) still show more prudence in their lending strategies. In particular, among G-SIBs, we show that loan spreads are on average higher when a lender has non-dilutive CoCos in its capital structure. Since our loan-level regressions control for borrower-year fixed effects, any difference in loan pricing is not a reflection of the borrower's credit risks but rather lenders' risk appetite.

In light of the aforementioned two empirical observations, we aim to understand in this paper why CoCos with no (or only weak) dilutive feature can be so prevalent in practice and what implications that such non-dilutive designs hold for banks' risk-taking incentives. Our analyses also allow us to derive conditions under which banks have incentives to issue dilutive CoCos that fully fulfill the securities' potential in correcting risk-taking incentives.

Our theory about the non-dilutive feature of CoCos builds on the basic observation that as going concern securities, CoCos need to be 'bailed in' when the bank that triggered the conversion/write-down remains afloat — albeit low in common equity capitalization. However, such a state of low equity capitalization is where the shareholders' incentives for risk-shifting are the strongest. Therefore, it is essential for CoCos to be

[4]In fact, among all G-SIBs that issued CoCos, HSBC was the only one whose stock price did not breach the CoCo conversion price upon the start of the COVID crisis. However, even in this case, the lowest point of the market price of the bank's common equity (about £2.83 per share) was very close to the bank's CoCo conversion price (£2.70 per share). When the bank's CET1 ratio drops dramatically in an actual banking crisis, the prevailing stock market price is very likely to breach the conversion price. Therefore, in our opinion, available evidence suggests all AT1 CoCo issued by G-SIBs are non-dilutive.

designed to mute such risk-shifting incentives. Indeed, if a bank's CoCos are highly dilutive, there will be little left for existing shareholders upon the CoCos' conversion. While the bank can be more resilient with the new common equity from the CoCos' conversion, the existing shareholders will benefit little from it. Dilutive conversions, therefore, can create incentives for existing shareholders to gamble for resurrection — in the hope of steering the bank away from the trigger event.

We highlight that non-dilutive CoCos are rather unique in the sense that they are junior to a bank's existing common equity. Indeed, the write-down (in the case of PWD CoCos) and the equity conversion at prices higher than the prevailing market price (in the case of equity conversion CoCos) would lead to net transfers from CoCo investors to existing equity holders. While this violates the absolute priority rule, it is such a design that makes non-dilutive CoCos particularly powerful in preventing gambling for resurrection as the bank draws near insolvency.

We analyze the design of CoCos in an agency model with two subsequent moral hazard problems. First, the banker can achieve low risk in its loan portfolio with costly screening and stay away from triggering CoCo conversion. When the risk is not adequately managed in the first place, however, the bank's cash flow could fall and trigger CoCo conversion. Knowing privately whether the bank is heading towards the trigger event, the banker can take a second moral hazard action: to gamble for resurrection. That is, to take on a risky project that would restore the cash flow and conceal the lack of screening to external investors, but at the risk of resulting in even bigger losses and bankruptcy.

The design of CoCos as going-concern securities can be fully characterized by payoffs to CoCo investors in a low state of the world (where the bank's financial health weakens and triggers CoCo conversion/write-down) and in a high state of the world (where the bank's financial health is strong and stays away from the trigger event), and setting payoffs in both the low state and high state can involve trade-offs between discouraging ex-ante vs. ex-post risk-taking. Let's start with the low state. When CoCos are non-dilutive upon conversion, they preserve shareholders' value in the state where the bank's cash flow is low and thereby help prevent gambling for resurrection. Non-dilutive CoCos, however, make screening less valuable to shareholders of the bank, which may end up triggering conversion more often. A similar trade-off arises in setting the payoff in the high state. Since the high payoff can be from proper screening or risk-taking, leaving a high payoff to shareholders in the high state can induce effort in screening but may also incentivize ex-post risk-shifting. In fact, the trade-offs in both states are connected because non-dilutive CoCos must offer greater payoffs to CoCo investors in the high state to satisfy the investors' participation constraint. This implies a relatively low payoff to shareholders in the high state and further reduces their ex-post risk-shifting incentives.

Our setting allows us to emphasize that the choice and the impact of (non-)dilutiveness of CoCos on risk-taking can be contingent on the capital position of the bank. We show that a non-dilutive CoCo can generate higher pledgeability for the bank since the design only tackles one moral hazard problem — to prevent gambling for resurrection. A trade-off can emerge when the bank chooses between dilutive and non-dilutive designs: while the former can induce better screening and risk management that lead to a greater NPV, the latter has the benefit of higher pledgeability and maximizing returns on equity. As a result, non-dilutive CoCos can be particularly attractive to banks with a limited amount of equity funding.

While we do not do a fully-fledged security design exercise to establish the optimality of (non-dilutive) CoCos, we compare CoCos with other loss-absorbing securities such as subordinated debt and non-voting shares in terms of correcting risk-taking incentives.[5] We show that CoCos can contain bank risk-taking for a wider range of parameters than each of the aforementioned securities and are never dominated by those securities for any given capital structure of the bank. More precisely, compared to subordinated debt, CoCos can avoid ex-post moral hazard when a bank has higher financing needs, and therefore CoCos deliver relatively higher ex-ante value. When compared to non-voting shares, CoCo increase the ex-ante funding opportunities of the bank because they are more effective at mitigating both moral hazard problems by tailoring the contract to the ex-post state of the bank, whereas equity inflexibly allocates a fixed fraction to outside investors, independently of the outcome.

Our paper contributes to the burgeoning literature on CoCos in two ways. First, it provides an explanation why CoCos are typically designed to be non-dilutive, consistent with the prevalence of PWD CoCos and the likely low equity value upon conversion for equity-conversion CoCos. Second, it sheds light on how designs of CoCos are related/determined by banks' balance sheet characteristics, which provides testable empirical hypotheses for future studies. We emphasize that CoCos' designs and their implications for banks' risk-taking behaviors need to be understood and assessed in the context of banks' broader capital structure. We predict that non-dilutive CoCos are more likely to be issued by banks that are less-than-ideally capitalized.

Our paper also contributes to the debate on the regulatory treatment of CoCos. While many promote CoCo as securities that can both absorb losses and prevent risk-taking, others are less convinced and have criticized CoCos as yet another way for banks to stretch their balance sheets and defer equity capitalization. Our model suggests that the design and the effectiveness of CoCos largely depend on the equity capitalization of banks. When a bank is sufficiently capitalized, it will optimally design its CoCos to be dilutive, and the CoCos can provide incentives for both screening and avoiding gambling for resurrection. On the other hand, when a bank is less capitalized, it will choose its CoCo design to be non-dilutive, which avoids gambling resurrection and allows more financing capacity for the bank. Our model suggests that, despite the generous

[5] Those securities are chosen for the comparison because they can absorb losses for senior debt holders and are also considered regulatory capital.

regulatory treatment with AT1 designation, CoCos are no substitutes for banks' equity capital. Instead, the effectiveness of CoCos in containing risk-taking relies on banks' equity capitalization. To an extent, one can interpret the prevalence of non-dilutive CoCos as indications that there are still room for further capitalization in the banking sector.

Related Literature: Many researchers, e.g., **??** and **?**, advocate CoCos as securities that can automatically replenish bank capital and can correct distorted bank risk-taking incentives with its equity dilution feature. **?** formally show that, with a market trigger, dilutive CoCos can penalize bank shareholders for risk-taking and promote financial stability.[6] **?** argue that with a properly designed dilution feature, CoCos can eliminate banks' incentive of risk-shifting — even during periods of financial distress. However, in light of the current market practice, the theories that promote CoCos' effectiveness in reducing bank risk-taking with strong equity dilution seem to have made an assumption more optimistic than market reality.[7]

Researchers like Admati have cast doubt on CoCo's role in promoting financial stability, considering the security yet another way for banks to satisfy capital regulations with a debt-like instrument instead of equity, instrumental for banks to boost returns on equity for their shareholders. **?**, **?** and **?**, in particular, expressed concern that non-dilutive CoCos can create even stronger risk-shifting incentives than subordinated debt due to the wealth transfer from CoCo investors to bank shareholders upon conversion. The concern can be rather valid since non-dilutive CoCos dominate the market. Our empirical findings provide a somewhat more reassuring message, as the loan-level regressions reveal that G-SIBs that issued CoCos (despite being non-dilutive) displayed more prudence in their lending strategies. Accordingly, we make a theoretical conjecture that strong dilution for an already undercapitalized bank can result in incentives for gambling for resurrection, in a way that the non-dilutiveness of CoCos can be a 'necessary evil' in containing risk-shifting.

Other than the non-dilutiveness of CoCos, the literature also raised other concerns regarding the hybrid securities. In a global-games framework, **?** argued that CoCos with its triggering event could lead to panic-driven runs of creditors; the triggering of the conversion can even generate negative information externalities for other banks with correlated returns. Therefore, a security that is designed to reduce individual bank insolvency risks can result in funding liquidity risk and potentially financial contagion.

[6] While both **?** and **?** focus on CoCos with market triggers, to the best of our knowledge, CoCos issued by major banks all have regulatory triggers associated with banks' CET1 ratio to qualify as AT1 capital.

[7] Some papers, like **?** and **?**, go further and consider CoCos as optimal securities with generic market frictions. We have not aimed for a strong claim as such, since CoCos have been issued only by banks in jurisdictions where the securities receive favorable regulatory treatment. Instead, we view CoCos as a constrained solution and study them in the context of banks' equity capitalization to understand how such balance sheet characteristics can affect the design and effectiveness of CoCos.

? document that in the only real-world case of bail-in with CoCos, the hybrid security was not converted before the bank failed, casting doubt that whether CoCos are in fact going-concern securities. **?** point out that CoCo investors may hedge against the risk of non-dilutive conversion on the side by short-selling the bank's equity. When their short-selling positions have a negative impact on the bank's equity price, CoCos' conversion can be self-fulfilling.

The theory paper most related to ours is **?**. The authors provide a theory to explain the prevalence of PWD CoCos, but their setting is such that PWD CoCos are optimal independent of a bank's overall capital structure. We instead emphasize that, despite the prevalence of non-dilutive CoCos, there can still be hope for CoCos to fulfill their full potential by being dilutive and preventing ex-ante risk-taking. Whether we can achieve that, as our model suggests, crucially depends on the equity capitalization of the bank.

On the empirical side, **?** show that banks' CDS spreads drop after their issuance of CoCos, which may be attributed to the loss-absorbing capacity of the hybrid securities or the correction of risk-taking incentives. **?** also document negative correlations between the issuance of equity conversion CoCos and bank-level risks such as the volatility of equity returns. Our empirical analysis goes one step further and establishes with syndicated loan data pricing that banks financed by CoCos have indeed shown more prudence in their loan pricing. Our theoretical prediction that non-dilutive CoCos can reduce risk-taking by undercapitalized banks can find its empirical support in **?**. The author shows via the Liability Management Exercises during the crisis, European banks booked capital gains at the cost of subordinated debt holders, leading to lower perceived risks from the market.

The remaining of the paper is organized as follows. Section 2 sets out our basic model. We study in Section 3 different CoCo designs – in terms of their feasibility, their requirements for corresponding equity capital levels, and the impacts on existing shareholder values. We show that non-dilutive CoCos can emerge for banks with an intermediate level of equity capitalization. Section 4 compares CoCos with common securities such as subordinated debt and new common equity. Section 5 provides an empirical evaluation on whether CoCos have reduced bank risk-taking with syndicated loan market data. Section 6 concludes.

2 The Model

The economy has three dates, $t = 0, 1, 2$, and comprises a bank, and four economic agents: the owner/banker, retail depositors, the FDIC, and outside investors. All agents are risk-neutral and the risk-free rate is zero.

The baseline capital structure of the bank comprises deposits from retail depositors, denoted by D, and equity. Equity holding is protected by limited liability. We assume that deposit insurance has been already paid to FDIC and the retail deposits are safe.[8]

The banker maximizes her wealth at $t = 0$ by investing in a loan portfolio, which requires 1 dollar of initial capital and has maturity $t = 2$. We assume $D < 1$, to avoid the trivial case no equity and no external financing are needed. To finance the project, the banker issues securities to outside investors, who break-even when they buy them. We will consider three alternative types of securities: CoCo bonds, subordinated debt, and non-voting shares. The banker has an endowment $E \geq 0$, which is currently invested in financial securities traded in competitive and arbitrage-free capital markets. Because trading financial securities is a zero-NPV activity, the banker will invest in the loan portfolio only if this is a positive-NPV decision and if E is higher than the financing gap between the investment cost of \$1 and the amount raised from depositors and external investors.

Conditional on undertaking the project, in the first period of the investment process the banker can screen the loans, which makes the portfolio risk-free with a sure return $R > 1$. The screening effort is non-contractible, though. If the banker shirks, she obtains an immediate private benefit, G, but leaves the bank exposed to the risk of loan delinquencies and defaults. The effect of loan delinquencies is to reduce the return to $R' \in]0, R[$ with probability p, while with probability $(1-p)$ the return remains R, where $p \in]0, 1[$. However, shirking does not lead to default, as per the following assumption:

Assumption 1. *We assume $R' > D$.*

Assumption 2. *The expected loss on loans with no screening exceeds the banker's private benefit: $G < p(R - R')$.*

Assumption 2 states that screening is socially efficient. Finally, we assume that the NPV of the investment in the loan portfolio is positive even if the banker shirks:

Assumption 3. *The expected cash flow of the loan portfolio with no screening is greater than the investment cost, $(1 - p)R + pR' > 1$, from which $p(R - R') < R - 1$.*

This assumption ensures that the banker can finance the project even when outside investors anticipate no screening effort. The exclusion of this assumption would lead to the counterfactual result that the bank would be able to raise money from investors only if the loan portfolio was risk-free. This would contradict the empirical evidence on the risk level of banks' assets.

While all parameters of the model are common knowledge to the investors, we have the following assumption:

[8] As it will be clear later, in equilibrium deposit insurance will never be used as depositors will always be fully repaid by the bank.

Assumption 4. *The return of the long-term investment can only be privately observed by the banker at $t = 1$.*

At $t = 1$, the banker has the option to invest in a follow-on short-term risky project, which requires no outlay and has cash flow at $t = 2$ of either $R - R'$ with probability $(1 - q)$ or $-R'$ with probability q, where $q \in]0, 1[$.

Assumption 5. *The NPV of the follow-on project is negative:* $(1 - q)R - R' < 0$.

One the one hand, the upside of this project restores the cash flow to R. On the other, the losses from the project can make the bank default, which occurs when the output is zero. In effect, taking this project is tantamount to shifting risk.[9]

Assumption 6. *The bank can be financed even if the banker shirks and takes the follow-on project:* $(1 - pq)R - 1 + pqD > 0$.

Although the follow-on project destroys values, the total cash flow to the bank is still positive. This assumption ensures the lending project will always be financed, where the expected value of the wealth transferred from FDIC upon the default of the deposit pqD is captured by the bank.

Assumption 7. *The regulator imposes taxes (or other penalties) on $2R - R'$ and $R - R'$ at $t = 2$, to restore a return R.*

Taking the risky project when the return at $t = 1$ is R gives an outcome at $t = 2$ of either $2R - R'$ or $R - R'$. As the return in $t = 2$ is public information, either of these two outcomes would reveal the banker's ex-post moral hazard action. Assumption 7 states that the regulator deters such a behavior by imposing taxes (or other penalties) that undo the effect of ex-post moral hazard. Therefore, the risk-shifting incentive is eliminated and the follow-on project will not be taken if the return at $t = 1$ is R. [10]

The timeline is in Figure 1. The model contains two moral hazard issues by assuming that both shirking and risk shifting are value destroying. The former issue has a long-term impact on the value of the bank. In comparison, the latter moral hazard issue is short-term, as it occurs only one period before the terminal date.

[9] For example, the banker may take position in derivatives for speculative purposes, or can extend more credit to a borrower whose credit quality has already deteriorated, betting on their resurrection.

[10] Notably, while also the return R at $t = 2$ can be the result of moral hazard actions, it is not possible for the regulator to implement the same deterrent as for the states $2R - R'$ and $R - R'$, because the return R occurs also when the banker screens loans. In fact, any punishment after the return R in $t = 2$ would encourage the banker to shirk.

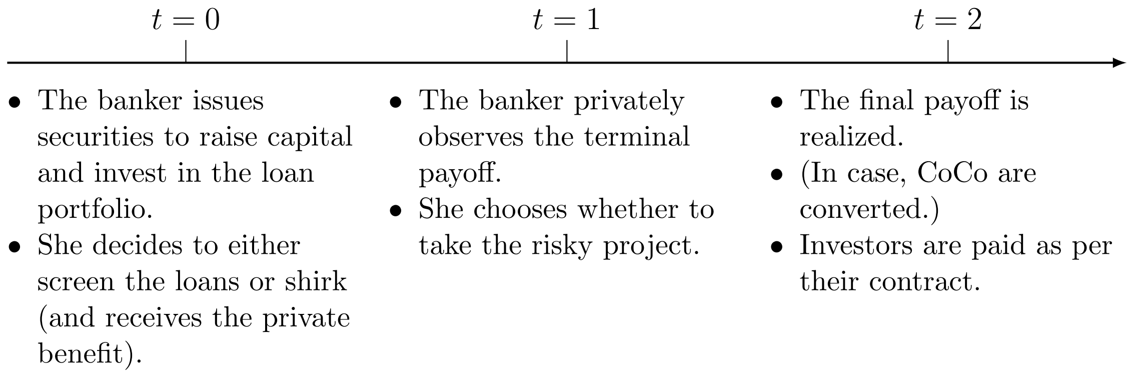


Figure 1: Timeline of the model

While not strictly required for our results, we add the following assumption to ensure that, if the banker's endowment is sufficiently high (that is, the bank is well capitalized), it is possible to achieve the first best outcome by issuing securities.

Assumption 8. *We assume that* $E + (R - 1) > \frac{G}{pq}$.

For the banker's investment problem, we analyze three alternative financing scenarios: CoCo bonds (C), plain debt (B), non-voting shares (S). As it will be clear later on, each security has (a vector of) design parameters, θ, with respect to which the banker optimizes her value. The investment decision given the choice of the security delivers the banker an expected net payoff $\Pi^j(\theta)$. Given the endowment, E, and the fair price of the security, denoted by P^j, the *required bank capital* is $K^j = 1 - D - P^j$, and the resource constraint is $E \geq 1 - D - P^j$, for $j = C, B, S$. The banker's program for security j is

$$\max_{\theta} \left\{ \Pi^j(\theta) - K^j(\theta) + E, \text{ subject to } E \geq K^j(\theta) \right\}, \tag{1}$$

where additional constraints may be imposed to ensure the feasibility of the security.

Intuitively, if E is sufficiently high, the banker can invest in the project by issuing risk-free securities (and if E is very high, there is no need to issue any securities). To avoid this trivial scenario, we assume that E is sufficiently low, and with no loss of generality in what remains of the paper we analyze the case $E = 0$. Under this condition, Assumption 8 becomes $pq(R-1) > G$, which has an intuitive interpretation, as it shows that, for first best to be attainable by issuing securities, the NPV of the investment destroyed by shirking and taking risk, on the left-hand side, must be higher than the private benefit.

In what follows, we analyze the solution of the banker's program with CoCo bonds, and then compare it to the solution with subordinated debt and non-voting shares.

3 CoCo bond

A CoCo bond is characterized by three parameters: the face value, F, the conversion ratio, $\gamma \geq 0$, and the conversion trigger X. At $t = 2$, if the return is below a predetermined threshold, X, the CoCo converts to γF equity. That is, upon conversion the CoCo investors get a fraction

$$\lambda = \frac{\gamma F}{E + \gamma F} \tag{2}$$

of equity, with $\lambda \in [0, 1[$, and the shareholders receive a fraction $1 - \lambda$ of total outstanding shares. For convenience, in what follows we will characterize the conversion ratio with λ through equation (2), the economic intuition being the same, as λ is monotonically increasing in γ. Hence, in what follows $\theta = (F, \lambda, X)$. The CoCo bonds are going-concern securities, meaning that the conversion threshold is higher than the default threshold, D. Given the restriction on the final outcome set by Assumption 7, whereby the maximum outcome is R, then the conversion threshold X is in our model naturally set in the interval $]R', R[$.[11] Figure 2 shows the ordering of the final terminal payoffs and the CoCo conversion interval.

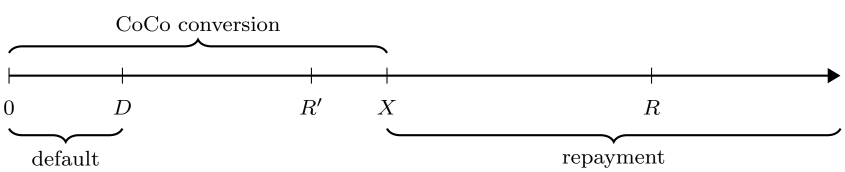


Figure 2: Conversion and repayment of CoCo bond.

Accounting for the moral hazard actions and limited liability, the payoffs to all the parties in different cash flow scenarios are shown in Table 1, with the exclusion of the banker's private benefits.

Table 1: Payoffs to all investors (excluding the private benefit).

Cash flow	Banker	CoCo investors	Depositors	FDIC
R	$R - D - F$	F	D	0
R'	$(1 - \lambda)(R' - D)$	$\lambda(R' - D)$	D	0
0	0	0	D	$-D$

[11] This implies that R' is the highest cash flow at which conversion is triggered. Of course, the CoCo is converted also if the return is lower than D, but in that case the CoCo investors get nothing, like the other shareholders.

While the CoCo bond investors can observe the terminal-date payoff of the bank, they cannot observe the banker's decisions at $t = 1$. As the CoCo bond market is competitive, investors pay at $t = 0$ the break-even price, $P(F, \lambda, X)$, for the bond issuance. The banker invests in the loan portfolio if the financing constraint, $E \geq 1 - D - P(F, \lambda, X)$, is satisfied. Given the contract design (X, F, λ), because X is fixed, the CoCo bond contract is fully characterized by the couple (F, λ), which is chosen in the set $\mathcal{C} = [0, R - D] \times [0, 1[$, where the upper bound $R - D$ for F is a consequence of limited liability of equity investment. Conditional on these parameters for the offered CoCo bond, the banker will adopt the strategy that maximizes her value (as opposed to the total value of the bank). Hence, given (F, λ), the expectation of the return for the CoCo bond investors depends on the banker's strategy, and the break-even price of the CoCo bond, $P(F, \lambda)$, reflects such an expectation.

After the screening decision at $t = 0$, the banker makes the risk shifting decision based on her private information on the cash flow at $t = 1$ and the objective to maximize the expected return. If at $t = 1$ she observes R, the banker will not take the risky project because, based on Assumption 7. But if she observes R', risk shifting is a positive NPV decision from her perspective, $(R - D - F)(1 - q) > 0$, because of limited liability. Alternatively, if she does not shift risk, she anticipates that conversion will happen if no action is taken, with equity value $(1 - \lambda)(R' - D)$. Figure 3 summarizes the equilibrium decisions made by the banker and the ensuing cash flow to equity (with the exclusion of the banker's private benefit).

From the above analysis, there are three strategies that the banker can follow depending on the offered CoCo bond contract (F, λ). The first is to screen at $t = 0$, and therefore not to shift risk at $t = 1$. The value to the banker in this case is

$$\Pi_0^C(F, \lambda) = R - D - F.$$

The second is to shirk at $t = 0$ but not to take any chances at $t = 1$, even if the outcome is R'. The value to the banker from this strategy, including the private benefit from shirking, is

$$\Pi_1^C(F, \lambda) = p(R' - D)(1 - \lambda) + (1 - p)(R - D - F) + G.$$

In the third strategy, the banker first shirks and then shifts risk if the outcome is R', with an overall value to the banker of

$$\Pi_2^C(F, \lambda) = (1 - pq)(R - D - F) + G.$$

Hence, although the CoCo bond contract is one, depending on (F, λ) it allows for three different outcomes. For such a contract, we will call *Design 0* the subset of $\mathcal{C}$ with no moral hazard action, *Design 1* the subset for which the banker shirks but does not shift risk, and *Design 2* the design with both shirking and risk-shifting conditional on a

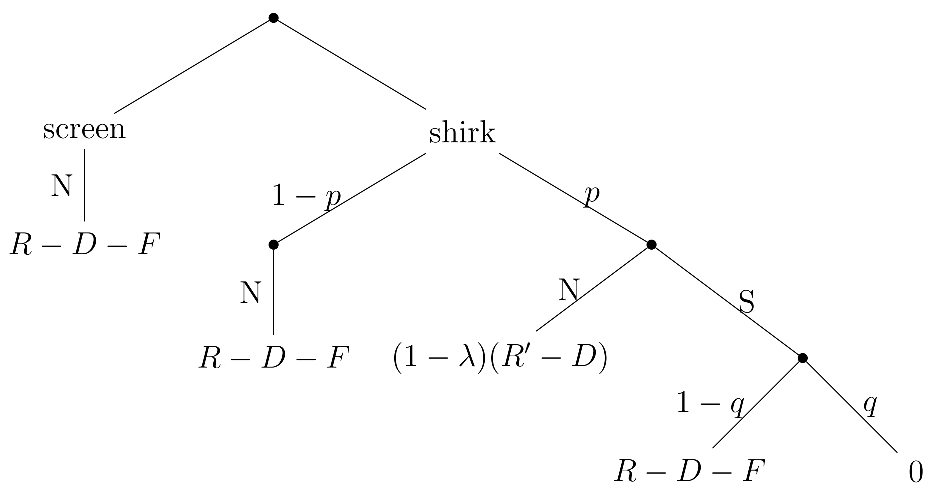


Figure 3: Cash flow to equity at $t = 2$ (with the exclusion of private benefit). First, the banker decides either to screen the loan portfolio, making the return safe at R, or to shirk, making the return risky. In the latter case, with probability p the return is R' and R otherwise. Next, the banker either leaves the initial investment unchanged (N), or shifts risk (S), in which case the incremental cash flow is $-R'$ with probability q or $R - R'$ otherwise.

low return. Design 0 is an uncompromising one, in the sense that no moral hazard by the banker is allowed. Design 1 allows shirking but not risk-shifting, and the private benefit extracted by the banker can be viewed as the necessary evil that financiers accept to finance the profitable project. Finally, Design 2 leaves the banker unrestricted.[12]

Before we analyze these designs, we show that the attainment of each design depends on the quantities

$$F_0 = R - D - \frac{G}{pq}, \qquad F_1 = R - D - \frac{R'-D}{1-q}, \qquad F_2 = R - R' - \frac{G}{p},$$

which in turn depends on the model parameters. It is easy to show that $F_0, F_1, F_2 \leq R - D$ under the assumptions made in the previous section. The relative position of these three quantities determines different scenarios regarding the feasibility of the CoCo bond contract. We have the following result.

Lemma 1. *Given Assumptions 1-7, only two scenarios are possible:*

1. $F_1 < F_2 < F_0$, *if* $\frac{G}{pq} < \frac{R'-D}{1-q}$ *and* $\frac{G}{pq} < R - D$, *where* $F_1 > 0$ *if and only if* $\frac{R'-D}{1-q} < R - D$;

[12]The total firm value (or welfare) in correspondence of the three strategies is respectively $W_0 = R$, $W_1 = (1-p)R + pR' + G$, $W_2 = (1-pq)R + G$. Given Assumptions 2 and 5, only the first strategy is socially efficient, and $W_0 > W_1 > W_2$.

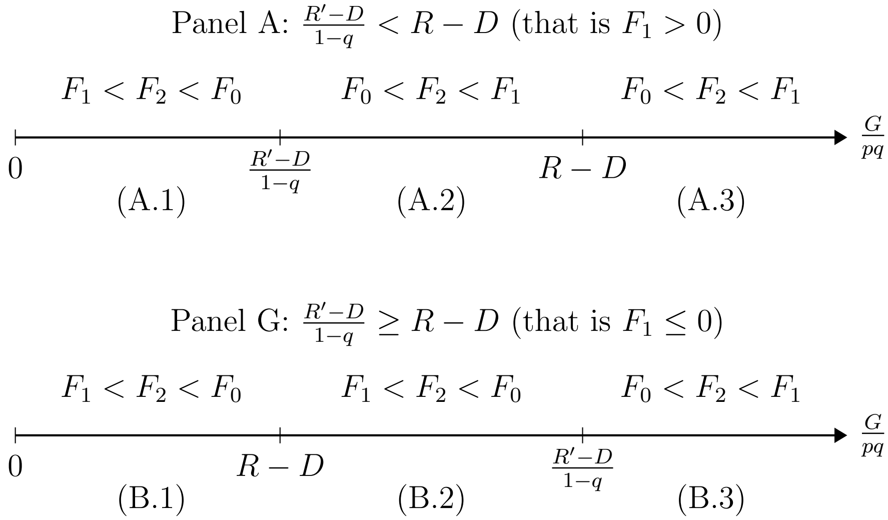


Figure 4: Cases for the design of the CoCo bond contract.

2. $F_0 < F_2 < F_1$, *if* $\frac{R'-D}{1-q} < R-D$ *and* $\frac{R'-D}{1-q} < \frac{G}{pq}$.

Proof. Simple algebra shows that there are two key cases to consider. The first is that $F_2 \geq F_1$ if and only if $\frac{G}{pq} \leq \frac{R'-D}{1-q}$, and this condition is also equivalent to $F_0 \geq F_2$. The second case is that $F_0 \geq 0$ if and only if $\frac{G}{pq} \leq R-D$. The relative position of the quantities $\frac{R'-D}{1-q}$ and $R-D$ generates the six different cases in Figure 4 (e.g., (B.2) is for $\frac{G}{pq} \in [R-D, \frac{R'-D}{1-q}[$, for which we have $F_1 < F_2 < F_0$). Because $F_1 > 0$ if and only if $\frac{R'-D}{1-q} < R-D$, in Figure 4 Panel (a) $F_1 > 0$ and in Panel (b) $F_1 \leq 0$. Also, if $\frac{G}{pq} = \frac{R'-D}{1-q}$, then $F_0 = F_1 = F_2$. If $F_0, F_1, F_2 \leq 0$, the lower bounds set by these quantities are redundant because F is non-negative by definition. Assumption 2 implies that $F_2 > 0$, which rules out both (B.2), because in it $F_0 < 0$, and (B.3) because in it $F_1 < 0$. After excluding these two cases, we are left with two possible scenarios. The first is $\frac{G}{pq} < \frac{R'-D}{1-q}$ and $\frac{G}{pq} < R-D$, which corresponds to both (A.1) and (B.1). The second is $\frac{R'-D}{1-q} < \frac{G}{pq}$, although $\frac{R'-D}{1-q} < R-D$, which corresponds to (A.2) and (A.3). □

The three designs of the CoCo bond depend also on the functions

$$\lambda_0(F) = \frac{pF + p(R'-R) + G}{p(R'-D)}, \qquad \lambda_1(F) = \frac{(1-q)F - (R-R') + q(R-D)}{R'-D},$$

which will be used to set constraints on λ. Both functions are linear and increasing in F. Simple algebra shows that

$$\lambda_0(F_2) = 0, \quad \lambda_0(F_0) = 1 - \frac{G}{pq}\frac{1-q}{R'-D}, \quad \lambda_0(R-D) = 1 + \frac{G}{p(R'-D)},$$

and

$$\lambda_1(F_1) = 0, \quad \lambda_1(F) \leq 1 \text{ for all } F \in [0, R - D].$$

If $\lambda_0(F)$ and $\lambda_1(F)$ set lower bounds on λ, these are redundant when they are negative.

3.1 Design 0: no moral hazard

To prevent the banker from taking any moral hazard actions, her value from screening should be greater than that of any strategies entailing shirking. As shown before, there are two such strategies, and therefore we require that two incentive compatibility conditions are satisfied: $\Pi_0^C \geq \Pi_1^C$ and $\Pi_0^C \geq \Pi_2^C$.

The first condition, is equivalent to $\lambda \geq \lambda_0(F)$, and sets a lower bound on equity claimed by CoCo investors upon conversion, making shirking less attractive to the banker. Because $\lambda \in [0, 1[$, the lower bound set for λ is binding if $\lambda_0(F) < 1$ (otherwise the contract is not feasible), that is under Assumption 1 if

$$F < R - D - \frac{G}{p}. \tag{3}$$

The second condition, sets an upper bound on the face value of the CoCo bond, $F \leq F_0$. Hence, Design 0 is infeasible if $F_0 < 0$, that is if $\frac{G}{pq} \geq R - D$.

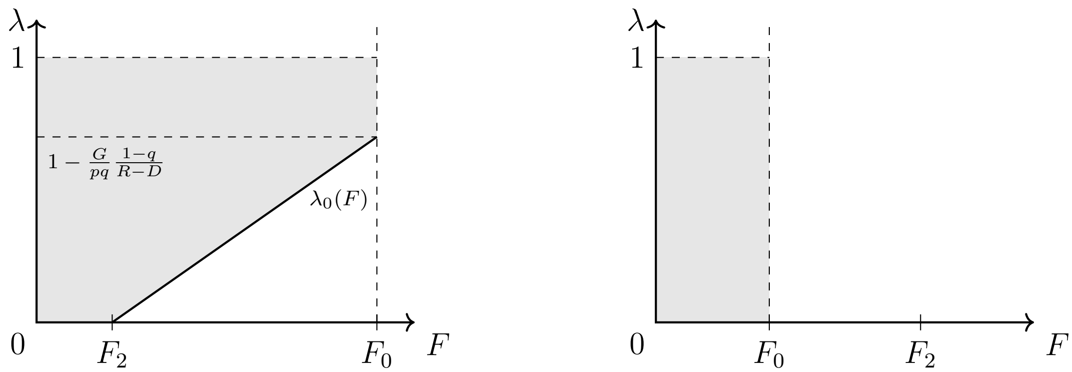
Under the assumptions set for the parameters of the model, both conditions (3) and $F \leq F_0$ set upper bounds on F, and if $q < 1$ the latter is more restrictive than the former. Hence, for $q < 1$, if $F \leq F_0$, then $\lambda_0(F)$ is lower than one and the contract design eliminates the banker's incentive to take either of the moral hazard actions.

Because $\lambda_0(F)$ is an increasing function (with slope $\frac{1}{R'-D}$) and $\lambda_0(F_2) = 0$ and $\lambda_0(F_0) = 1 - \frac{G}{pq}\frac{1-q}{R'-D}$, Design 0 is feasible at F_0 if and only if $\frac{G}{pq} < \frac{R'-D}{1-q}$. In the alternative case of $\frac{G}{pq} \geq \frac{R'-D}{1-q}$, then $\lambda_0(F_0) < 0$ and $F_0 < F_2$. In this case, the contract is feasible with unrestricted λ for all $F < F_0$, if $F_0 > 0$, which is equivalent to $\frac{G}{pq} < R - D$.

If Design 0 is feasible, the CoCo bond is risk-free, and its price equates the face value. We have just proved the following lemma.

Lemma 2. *With reference to Lemma 1: in Scenario 1, Design 0 is attained if $F \leq F_0$ and $\lambda \geq \max\{\lambda_0(F), 0\}$; in Scenario 2 with the additional restriction $\frac{G}{pq} < R - D$, Design 0 is attained if $F \leq F_0$ and $\lambda \in [0, 1[$. In these scenarios, the price of the CoCo bond is $P_0^C(F, \lambda) = F$.*

Lemma 2 indicates that offering the CoCo investors a large share of equity upon conversion creates an incentive for the banker to screen the loan portfolio. At the same



(a) $\frac{G}{pq} < \frac{R'-D}{1-q}$ and $\frac{G}{pq} < R-D$ (b) $\frac{R'-D}{1-q} \leq \frac{G}{pq} < R-D$

Figure 5: Feasibility of Design 0 of CoCo bond.

time, a low face value, F, makes risk-free (or low risk, in general) investment attractive enough for the banker.

Figure 5 describes the subset of $\mathcal{C}$ for which Design 0 can be obtained in the scenarios where this design is feasible. In Panel (a), because $\frac{G}{pq} < \frac{R'-D}{1-q}$, then $1-\frac{G}{pq}\frac{1-q}{R-D} \in]0,1[$. Based on Lemma 1, in the alternative case $\frac{R'-D}{1-q} \leq \frac{G}{pq}$, we have $F_0 < F_2$ and $\lambda_0(F_0) < 0$ and the design is feasible only if $\frac{G}{pq} < R-D$, for which $F_0 > 0$.

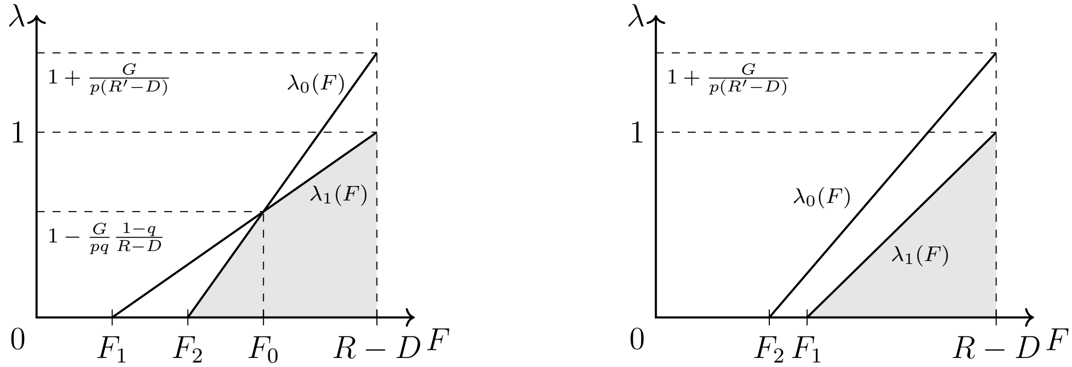
3.2 Design 1: the "necessary evil"

We consider a CoCo design that allows the banker to capture the private benefits by shirking but not to shift risk at $t = 1$ if she learns that the terminal payoff is R'.

The banker would not take more risk if $\Pi_1^C \geq \Pi_2^C$, that is $\lambda \leq \lambda_1(F)$, which sets an upper bound on λ. The set for λ defined by the latter condition is non-empty, and therefore the contract is feasible, if $\lambda_1(F) \geq 0$, that is $F \geq F_1$. The economic intuition of the lower bound for F set by F_1 is that for given R and D, if $R'-D$ or q are small, CoCo bond holders require F to be large enough to make risk shifting less attractive to the banker. At the same time, $\lambda_1(F)$ becomes larger for a higher F.

The banker does not screen the loan portfolio if $\Pi_1^C > \Pi_0^C$, which is equivalent to $\lambda < \lambda_0(F)$. This design is feasible only if the set of λ defined by $\lambda < \lambda_0(F)$ is non-empty, which occurs if $\lambda_0(F) > 0$, that is $F > F_2$.

Altogether, this design allows shirking and avoids risk shifting if $\lambda \leq \lambda_0(F)$ and $\lambda \leq \lambda_1(F)$, which set an upper bound on λ, and if $F \geq F_1$ and $F > F_2$, which set a lower bound for F. For short, $F \geq \max\{F_1, F_2\}$ and $\lambda \leq \min\{\lambda_0(F), \lambda_1(F)\}$.



(a) $\frac{G}{pq} < \frac{R'-D}{1-q}$ and $\frac{G}{pq} < R - D$

(b) $\frac{R'-D}{1-q} \leq \frac{G}{pq}$

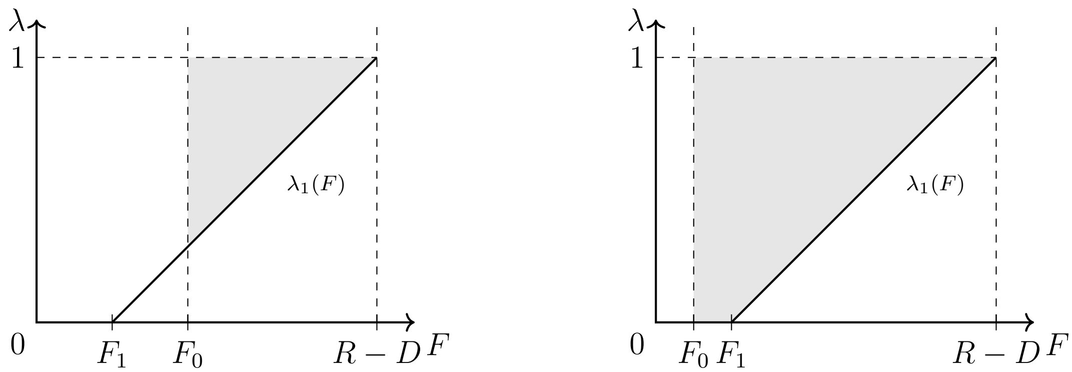
Figure 6: Feasibility of Design 1 of CoCo bond.

To specify the feasible region of this design, we consider two possible scenarios for the model parameters. The first is $\frac{G}{pq} < \frac{R'-D}{1-q}$, then $\lambda_0(F) \geq \lambda_1(F)$ if and only if $F \geq F_0$. Figure 6, Panel (a) shows this case, in which Design 1 is attained for $F \in [F_2, F_0]$ and $\lambda \leq \lambda_0(F)$ and for $F \in]F_0, R - d]$ and $\lambda \leq \lambda_1(F)$. The second scenario is $\frac{G}{pq} \geq \frac{R'-D}{1-q}$, for which $\lambda_0(F) > \lambda_1(F)$ for all $F \geq 0$. In this case, shown in Panel (b) of Figure 6, Design 1 is feasible for $F_1 < F \leq R - D$ and $\lambda \leq \lambda_1(F)$. Figure 6 presents the case $\frac{G}{pq} < R - D$, which is equivalent to $F_0 > 0$. However, the result does not change if $F_0 < 0$.

We have proved the following lemma.

Lemma 3. *With reference to Lemma 1: in Scenario 1, Design 1 is attained if $F \geq F_2$ and $\lambda \leq \min\{\lambda_0(F), \lambda_1(F)\}$; in Scenario 2, Design 1 is attained if $F \geq F_1$ and $\lambda < \lambda_1(F)$. Far all these cases, $P_1^C(F, \lambda) = (1-p)F + p(R' - D)\lambda$.*

Design 1 is the necessary compromise when the funding condition must be met but shirking is inevitable because of the large private benefit. Intuitively, this design triggers shirking because the face value has to be set high enough to fund investment, but hinders risk shifting by offering the CoCo holders a smaller cut of payoff upon conversion. With probability p, the banker observes R' at $t = 1$ and knows conversion will be triggered if no further decision is made. At this point, the banker can only choose between the dilution of share value due to CoCo bond conversion and shifting risk. The latter becomes more attractive if λ is low, and the banker receives a larger share of the return upon conversion. Contrary to Design 0, which is achieved for a high λ, with Design 1 the banker keeps a larger proportion (i.e., a larger $1 - \lambda$) and gives up risk-shifting. Such a design avoids the second value-destroying action and attracts the outside investors. Differently from Design 0, under Design 1 the CoCo bond is risky.



(a) $\frac{G}{pq} < \frac{R'-D}{1-q}$ and $\frac{G}{pq} < R-D$ (b) $\frac{R'-D}{1-q} \leq \frac{G}{pq}$ and $\frac{G}{pq} < R-D$

Figure 7: Feasibility of Design 2 of CoCo bond.

Note that Lemma 3 allows $\lambda = 0$. Hence, PWD CoCos, for which γ is zero and shareholders are not diluted upon conversion (that is, $\lambda = 0$), are special cases of Design 1. Our model allows to interpret the zero-γ feature as a way to discourage the banker from taking excessive risks when the ex-post risk-shifting incentive is strong. In other words, PWD CoCos might be used to eliminate the ex-post moral hazard actions.

3.3 Design 2: unrestricted actions

This design gives the banker the incentive to both shirk and shift risk if conditions $\Pi_2^C \geq \Pi_0^C$ and $\Pi_2^C \geq \Pi_1^C$ are simultaneously met. The first condition is equivalent to $F \geq F_0$. This condition is always attainable because $F_0 < 1$, under the assumptions of the model. The second condition is equivalent to $\lambda \geq \lambda_1(F)$. Also this condition is always attainable, because $\lambda_1(F) \leq 1$ for the relevant values of the contractual parameters (F, λ). At the same time, if $\lambda_1(F) < 0$, which occurs for $F < F_1$, λ is unrestricted in $[0, 1[$.

There are two possible scenarios for this case. In the first, $\frac{G}{pq} < \frac{R'-D}{1-q}$ and $F_0 > F_1$, as shown in Panel (a) of Figure 7. In the second $\frac{G}{pq} \geq \frac{R'-D}{1-q}$ and $F_0 \leq F_1$, as represented in Panel (b) of Figure 7. From Lemma 1, $F_0 \geq 0$ if $\frac{G}{pq} \leq R - D$. Figure 7 represents this case. However, the results do not change if $F_0 \geq 0$, as in this case any $F \in [0, R-D]$ is consistent with this design.

Because this designs allows for shirking and risk-shifting, the CoCo bond has a risky return and its price is $(1 - pq)F$. We have proved the following lemma.

Lemma 4. *With reference to Lemma 1: in Scenario 1, Design 2 is attained if* $F \geq F_0$ *and* $\lambda \geq \lambda_1(F)$*; in Scenario 2, Design 2 is attained if* $F \geq F_0$ *and* $\lambda \geq \max\{\lambda_1(F), 0\}$*. In all these cases, the price of the CoCo bond is* $P_2^C(F, \lambda) = (1 - pq)F$*.*

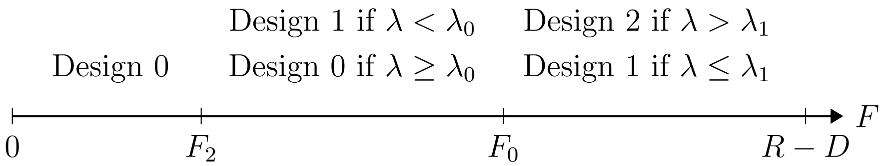


Figure 8: Feasible designs of the CoCo bond contract (under Scenario 1).

3.4 Optimal design of CoCo bond

We will focus on Scenario 1 of Lemma 1, in which $F_1 < F_2 < F_0$, because this is the relevant scenario for Design 1 to emerge as optimal, and because, in the alternative Scenario 1, it may be $F_0 < 0$, which would make it impossible to get a first best outcome. Figure 8 summarizes the feasible designs of the CoCo bond vis-a-vis the face value, F, which will be relevant later on.

The banker's program in (1) with CoCo becomes

$$\max_{(i,F,\lambda)} \left\{ \Pi_i^C(F,\lambda) - K_i^C(F,\lambda), \text{ subject to } K_i^C(F,\lambda) \leq 0 \right\},$$

where the optimization is done across different designs, i, and design parameters, (F, λ), with additional constraints deriving from the feasibility of each design i, as illustrated previously (e.g., Design 1 is possible if $F \in [F_2, R - D]$).

In what follows, we analyze the optimal design of CoCo bonds in relation to the financing conditions of the banker. Intuitively, the bankers potentially faces a trade-off on the choice of the design of the CoCo bond: on the one hand a design that allows for more moral hazards delivers an higher ex post value to the banker, which should be reflected in a higher expected payoff Π_i^C; on the other, such a design reduces the ex post payoff of the external financiers, and therefore has a lower price, which increases the required capital contribution by the banker, K_i^C. We set to analyze this tradeoff here below.

To solve the banker's program, we will first determine the value of the objective function after it has been optimized with respect to (F, λ) in each design. We denote by $\mathcal{E}_i^C$ the optimal value to the banker from Design i. Next, we will compare such values across the three designs, conditional on their feasibility, and determine the optimal design contingent on the financing conditions of the banker. We focus on the case $F_1 < 0$, which is equivalent to $(1-q)R - R' + qD < 0$. This condition is satisfied when the NPV of the risk-shifting action is negative and large, in particular larger than qD. The latter occurs, for a given negative NPV of the risk-shifting action, when the bank has issued little deposits. The case $F_1 \geq 0$ is not key for our analysis and is relegated to Appendix A.

The following lemma determines the optimal value in each design.

Lemma 5. *In Scenario 1 of Lemma 1, the optimal value to the banker in each design is*

$$\mathcal{E}_0^C = R - 1 \textit{ for } F > 1 - D \textit{ and } F \in [0, F_0],$$

$$\mathcal{E}_1^C = pR' + (1-p)R - 1 + G \textit{ for } F > \frac{1 - D - p(R' - D)\lambda}{1-p} \textit{ and } F \in [F_2, R - D],$$

$$\mathcal{E}_2^C = (1 - pq)R - 1 + pqD + G \textit{ for } F > \frac{1 - D}{1 - pq} \textit{ and } F \in]F_0, R - D].$$

Proof. For Design 0, if $K_0^C \leq 0$, which is equivalent to $F \geq 1 - D$, we have

$$\Pi_0^C - K_0^C = R - D - F - (1 - D - F) = R - 1.$$

Hence, with this design, the banker has a value of zero if F is low, and $R - 1 > 0$ if F is high. A necessary condition for the maximum value to be achievable is $1 - D < F_0$, that is $\frac{G}{pq} < R - 1$, which is equivalent to Assumption 8.

For Design 1, if $K_1^C \leq 0$, that is $F \geq \frac{1-D-p(R'-D)\lambda}{1-p}$, we have

$$\begin{aligned}\Pi_1^C - K_1^C = p(R' - D)(1 - \lambda) + (1-p)(R - D - F) + G - [1 - D - (1-p)F - p(R' - D)\lambda] \\ = pR' + (1-p)R - 1 + G.\end{aligned}$$

If alternatively $F < \frac{1-D-p(R'-D)\lambda}{1-p}$, then the banker's value is zero. This design is feasible if $F < R - D$.

Finally, for Design 2, if $K_2^C \leq 0$, which is equivalent to $F \geq \frac{1-D}{1-pq}$, we have

$$\begin{aligned}\Pi_2^C - K_2^C = (1 - pq)(R - D - F) + G - [1 - D - (1 - pq)F] \\ = (1 - pq)R - 1 + pqD + G.\end{aligned}$$

In the opposite case in which $F < \frac{1-D}{1-pq}$, the banker's value is zero. This design is feasible if $F < R - D$. Hence, the maximum can be achieved if $\frac{1-D}{1-pq} < R - D$, which is always satisfies from Assumption 6. $\square$

In Lemma 5, the optimal value in Design 1, differently from Design 0 and 2, depends on a parameter, λ, with respect to which the value $\mathcal{E}_1^C$ must be optimized. This is done later on.

The next lemma shows that, when Design 0 and 1 are both possible, the former delivers a higher value for the banker, and when Design 1 and 2 are both possible, the latter has a lower value for the banker.

Lemma 6. *Under Scenario 1 of Lemma 1, and for $F_1 < 0$, we have $\mathcal{E}_0^C > \mathcal{E}_1^C$ for $F \in [F_2, F_0]$ and $\mathcal{E}_1^C > \mathcal{E}_2^C$ for $F \in]F_0, R - D]$.*

Proof. $\mathcal{E}_0^C > \mathcal{E}_1^C$ is equivalent to $R - 1 > pR' + (1-p)R - 1 + G$, that is $p(R - R') > G$, which is Assumption 2. $\mathcal{E}_1^C > \mathcal{E}_2^C$ is equivalent to $pR' + (1-p)R - 1 + G > (1-pq)R - 1 + pqD + G$ that is, $R - D < \frac{R'-D}{1-q}$, which is equivalent to $F_1 < 0$. □

For $F \in [0, F_2[$, only a risk-free design is feasible and for $F > F_2$ more than one design is feasible. In the following lemma, we show that when two designs are possible for the same value of $F < F_0$, then banker's value without moral hazard is higher than the value with only shirking. Secondly, if $F > F_0$, the banker's value with only shirking is higher than the one with both shirking and risk-shifting, if excessive risk has a large welfare cost.

Lemma 7. *Under Scenario 1 of Lemma 1, if $F_1 < 0$,*

- *for $F \in [F_2, F_0]$, such that the budget condition $F > 1 - D$ is satisfied, Design 0 is optimal;*
- *for $F \in]F_0, R - D]$ such that the budget condition $F > \frac{1-D-p[(R-R')-q(R-D)]}{1-pq}$ is satisfied, Design 1 is optimal.*

Proof. In the interval $[F_2, F_0]$, both Design 0 and 1 are possible, and from Figure 8 the first is feasible if $\lambda \geq \lambda_0(F)$ and the second is feasible if $\lambda < \lambda_0(F)$. From Lemma 5, Design 1 delivers the value $\mathcal{E}_1^C$ for the banker in the interval $[F_2, F_0]$ if

$$\frac{1 - D - p(R' - D)\lambda}{1 - p} < F_0 \quad \Leftrightarrow \quad \lambda > \frac{1 - (1-p)R - pD + (1-p)\frac{G}{pq}}{p(R' - D)},$$

which sets a lower bound on λ. If for $F \in [F_2, F_0]$

$$\frac{1 - (1-p)R - pD + (1-p)\frac{G}{pq}}{p(R' - D)} > \lambda_0(F),$$

Design 0 trivially dominates Design 1 because the latter has no value for the banker. In the opposite case, Design 1 has positive value if $F > \frac{1-D-p(R'-D)\lambda}{1-p}$. To optimize Design 1 with respect to λ, the threshold $\frac{1-D-p(R'-D)\lambda}{1-p}$ should be minimized, which occurs if λ is set equal to the upper bound of the interval in which Design 1 is feasible, that is $\lambda = \lambda_0(F)$. Hence, Design 1 delivers the maximum value, $\mathcal{E}_1^C$, for

$$F > \frac{1 - D - p(R' - D)\lambda_0(F)}{1 - p} \quad \Leftrightarrow \quad F > 1 - D + p(R - R') - G.$$

However, as shown in Lemma 6, the value of Design 1 is lower than the one of Design 0, and a higher F is required to achieve $\mathcal{E}_1^C$ from Design 1, as $1 - D + p(R - R') - G > 1 - D$, which is equivalent to Assumption 2. From this we can conclude that for all $F \in [F_2, F_0]$, Design 0 dominates Design 1.

In the interval $]F_0, R-D]$ both Design 1 and 2 are possible, and the first is feasible for $\lambda < \lambda_1(F)$ and the second for $\lambda \geq \lambda_1(F)$. From Lemma 5, Design 1 delivers $\mathcal{E}_1^C$ if

$$\frac{1-D-p(R'-D)\lambda}{1-p} < R-D \quad \Leftrightarrow \quad \lambda > \frac{1-(1-p)R-pD}{p(R'-D)},$$

which sets a lower bound on λ. If this lower bound is, for $F \in]F_0, R-D]$, higher than $\lambda_1(F)$, Design 1 has no value to the banker. Then, the condition on F for Design 1 to have value $\mathcal{E}_1^C$ is

$$\frac{1-(1-p)R-pD}{p(R'-D)} < \lambda_1(F) \quad \Leftrightarrow \quad F > \frac{1-(1-p)R-pD+p[(R-R')-q(R-D)]}{p(1-q)}.$$

There is at least an F for which the above inequality holds true if

$$\frac{1-(1-p)R-pD+p[(R-R')-q(R-D)]}{p(1-q)} < R-D \quad \Leftrightarrow \quad (1-p)R+pR' > 1.$$

Therefore, because of Assumption 3, Design 1 has value $\mathcal{E}_1^C$ if it can be implemented. To maximize the chance of investing in it, the threshold for F should be minimized, which occurs if the banker chooses $\lambda = \lambda_1(F)$. Therefore, the maximum value of this design is delivered for

$$F > \frac{1-D-p(R'-D)\lambda_1(F)}{1-p} \quad \Leftrightarrow \quad F > \frac{1-D+p[(R-R')-q(R-D)]}{1-pq}.$$

From Lemma 6, for $F_1 < 0$ the optimal value of Design 2 is lower than the one of Design 1, and there is a higher threshold on F to achieve $\mathcal{E}_2^C$ from Design 2, as

$$\frac{1-D+p[(R-R')-q(R-D)]}{1-pq} < \frac{1-D}{1-pq},$$

because $R-R' < q(R-D)$ is equivalent to $F_1 < 0$. From this, we can conclude that, in the interval $]F_0, R-D]$, Design 1 delivers a higher value for lower F, which dominates Design 2. $\square$

To summarize, under the assumptions that lead to Scenario 1, for each F there is only one optimal design of the CoCo bond. Focussing on this case, Design 0 is optimal for $F \in [0, F_0]$. Lemma 7 shows that the design with "necessary evil" emerges as optimal for $F \in]F_0, R-D]$ under the assumption $F_1 < 0$.

Lemma 7 shows the optimality of CoCo bond in relation to the face value parameter, F, and implicitly to λ. However, to discuss the optimality with respect to the banker's financing conditions, and vis-à-vis the other types of securities, we need to restate the result in terms of the amount, P^C, raised by issuing the CoCo bond.

Proposition 1. *Under Scenario 1 of Lemma 1, if $F_1 < 0$ and $\frac{G}{pq} > p(R - R')$, the banker's value as a function of the amount raised by issuing CoCo bonds is*

$$\mathcal{E}^C(P) = \begin{cases} R - 1 & \text{if } P \in [1 - D, R - D - \frac{G}{pq}] \\ pR' + (1-p)R - 1 + G & \text{if } P \in]R - D - \frac{G}{pq}, R - D - p(R - R')] \end{cases}$$

Proof. The break-even price of the CoCo bond is

$$P^C(F) = \begin{cases} F, & \text{if } F \in [1 - D, F_0], \\ p(R' - D)\lambda + (1-p)F, & \text{if } F \in]\max\{\frac{1-D-p[(R-R')-q(R-D)]}{1-pq}, F_0\}, R - D]. \end{cases}$$

For $F \leq F_0$, $P^C(F) = F$ because Design 0 can be used, and hence the amount raised exactly reflects the boundaries for F. For $F > F_0$, the banker chooses $\lambda = \lambda_1(F)$ as we proved in Lemma 7. Hence, $P^C(F) = (1 - pq)F - p(R - R') + pq(R - D)$, which gives $\mathcal{E}_1^C$.[13]

There are two possible cases:

a) if $\frac{1-D-p[(R-R')-q(R-D)]}{1-pq} > F_0$, Design 1 is optimal for $F \in]\frac{1-D-p[(R-R')-q(R-D)]}{1-pq}, R - D]$. Given the restriction on F for this scenario, $P^C \in [1 - D, R - D - p(R - R')]$.

b) if $\frac{1-D-p[(R-R')-q(R-D)]}{1-pq} \leq F_0$, then Design 1 is optimal for $F \in]F_0, R - D]$. Therefore, $P^C \in [R - D - \frac{G}{pq} - p(R - R') + G, R - D - p(R - R')]$. Notably, $R - D - \frac{G}{pq} - p(R - R') + G < R - D - \frac{G}{pq}$ by Assumption 2.

For $P \in [1-D, R-D-\frac{G}{pq}]$ under (a), or for $P \in [R-D-\frac{G}{pq}-p(R-R')+G, R-D-\frac{G}{pq}]$ under (b), both designs can be financed, but the banker prefers the one with the higher value, $\mathcal{E}_0^C$.

Finally, in order to avoid the trivial case with only the first-best choice, we check if the maximum amount that can be raised with Design 0, $R - D - \frac{G}{pq}$, is lower than the maximum amount that can be raised with Design 1, $R - D - p(R - R')$. This is the case if $R - D - \frac{G}{pq} < R - D - p(R - R')$, that is $\frac{G}{pq} > p(R - R')$. □

In Proposition 1, we focus on the case $\frac{G}{pq} > p(R - R')$, under which Design 1 is not dominated. We will make the same assumption for the remaining part of the analysis. The opposite case, $\frac{G}{pq} \leq p(R - R')$, is relegated to Appendix B.

[13]Design 2 is dominated by Design 1, and we can therefore exclude it from our analysis. Indeed, for $F_1 < 0$, the price of Design 2, $(1 - pq)F$, is always lower than the price of Design 1, $(1 - pq)F - p(R - R') + pq(R - D)$, for all F in which both designs are feasible. Therefore, Design 1 raises more capital and delivers a higher value for the banker than Design 2.

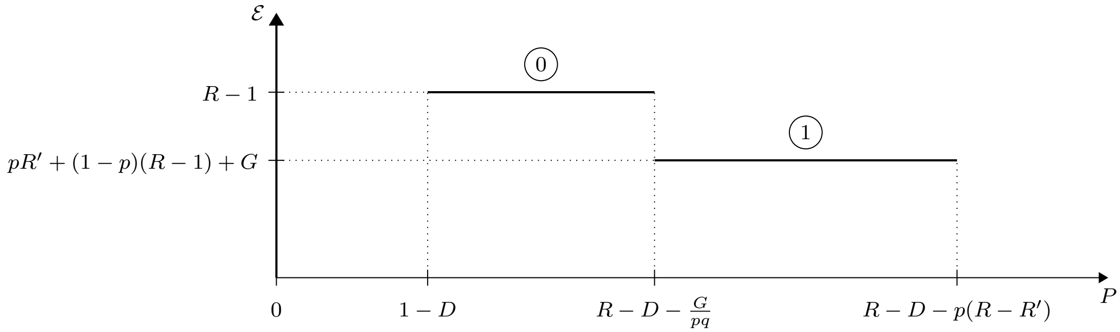


Figure 9: Optimal values to the banker against the amount raised by issuing CoCo bonds (with $\frac{G}{pq} > p(R-R')$).

Figure 9 plots the banker's optimal value vis-à-vis the capital raised from outside investors. For $P^C < 1-D$, the bank cannot raise enough to fund the project, so her value is zero. If the banker's financing conditions require $P^C \in [1-D, R-D-\frac{G}{pq}]$, Design 0 can be afforded, whereby both moral hazard actions are avoided, and the first best value $R-1$ is achieved. If the banker's conditions require an amount higher than $R-D-\frac{G}{pq}$ to invest in the project, then Design 1 must be used. Hence, a design with "necessary evil" is chosen by a relatively undercapitalized bank.

Notably, under the assumptions that make Design 1 dominant for relatively high face value, F, the optimal λ is chosen equal to $\lambda_1(F)$. Hence, given F, the optimal conversion ratio is inversely proportional to $R'-D$ and to the NPV of the risk-shifting project, $(R-R')-q(R-D) < 0$, which is equivalent to $F_1 < 0$. In other words, the smaller is the welfare cost of the risk-shifting action and/or the higher R' relative to D, the smaller λ and the conversion ratio, γ, of the CoCo design with necessary evil.

4 Comparison of CoCo bonds with other securities

In this section, we compare CoCo bonds to two alternative securities, subordinate debt and non-voting shares, to analyze the relative efficiency of CoCo bonds. For each alternative security, we first investigate the banker's incentives and profitability, and next we compare such profitability to the one achieved using CoCo bonds under the same financing conditions. Also in this case we will focus on Scenario 1 of Lemma 1, and the case $F_1 < 0$. The case $F_1 \geq 0$ is in Appendix A.

4.1 Subordinated debt

The design parameter with subordinated debt is the principal amount, B. As we did for CoCo bonds, also in this case three designs are in principle possible depending on the number of moral hazard actions they allow. The associated expected payoffs to the banker are respectively

$$\Pi_0^B = R - D - B,$$

$$\Pi_1^B = p \max\{R' - D - B, 0\} + (1-p)(R - D - B) + G,$$

and

$$\Pi_2^B = (1 - pq)(R - D - B) + G.$$

We have the following preliminary results regarding the feasibility of subordinated debt contracts.

Lemma 8. *Under Scenario 1 of Lemma 1, Design 0 is attained if $B \leq F_0$, and $P_0^B = B$.*

Proof. The banker screens the loan portfolio only if both incentive compatibility conditions, $\Pi_0^B > \Pi_1^B$ and $\Pi_0^B > \Pi_2^B$, are met. As for the first condition, we consider two scenarios: The first is $B > R' - D$, for which $\Pi_0^B > \Pi_1^B$ is equivalent to $B < R - D - \frac{G}{p}$. For condition $B > R' - D$ to be consistent with $B < R - D - \frac{G}{p}$ it must be $R' - D < R - D - \frac{G}{p}$, which is equivalent to $p(R - R') > G$, that is Assumption 2. The second scenario is $B \leq R' - D$, for which $\Pi_0^B > \Pi_1^B$ is equivalent to $p(R - R') > G$, which is always true under Assumption 2. Combining the two scenarios we conclude that $\Pi_0^B > \Pi_1^B$ if $B < R - D - \frac{G}{p}$. The second condition puts the same restriction on the debt principal as $\Pi_0^C > \Pi_2^C$ in the CoCo bond, that is $B \in [0, F_0]$. The reason for having the same condition for both securities is that a CoCo bond would not be converted and remains equal to a corporate bond for both Design 0 and Design 2. This bond-like feature also leads to the same budget constraint and value to the banker for both bonds and CoCo bonds. Because $R - D - \frac{G}{p} > F_0$, the upper bond on B is F_0. □

Lemma 9. *Under Scenario 1 of Lemma 1, Design 1 is never feasible.*

Proof. Design 1 would be feasible if $\Pi_1^B > \Pi_0^B$ and $\Pi_1^B > \Pi_2^B$. The first condition is equivalent to $B > R - D - \frac{G}{p}$. As for the second, $\Pi_1^B - \Pi_2^B = p \max\{R' - D - B, 0\} - p(1-q)(R - D - B)$. If $B > R' - D$, it becomes $\Pi_1^B - \Pi_2^B = -p(1-q)(R - D - B) < 0$. So, feasibility of Design 1 requires $B \leq R - D$. Alternatively, if $B \leq R' - D$, the condition becomes $\Pi_1^B - \Pi_2^B = p(R' - D - B) - p(1-q)(R - D - B)$, which is equivalent to

$$B < \frac{R' - (1-q)R}{q} - D.$$

Overall, $\Pi_1^B > \Pi_2^B$ if $B \leq R' - D$ and $B < \frac{R'-(1-q)R}{q} - D$. Because

$$\frac{R' - (1-q)R}{q} - D < R' - D \qquad \Leftrightarrow \qquad \frac{(1-q)(R'-R)}{q} < 0,$$

then $\Pi_1^B > \Pi_2^B$ for $B < \frac{R'-(1-q)R}{q} - D$. For Design 1 to be feasible, it should be

$$\frac{(1-q)(R'-R)}{q} + R' > R - D - \frac{G}{p} \qquad \Leftrightarrow \qquad \frac{p(R'-R)+qG}{pq} > 0.$$

However, the opposite is true because $p(R-R') > G > qG$ for $q \in]0,1[$ and Assumption 2. Therefore, Design 1 cannot be feasible. □

Lemma 9 states that the banker would never issue subordinated debt under Design 1. This is because the banker's risk-shifting incentives are increased by a higher face value B, due to her limited liability. On the other hand, at a low B for which default is not a problem, the value destroyed by shirking would be greater than the private benefit, so the banker screens the loan portfolio and avoids such a cost. Overall, the banker either takes or avoids both moral hazard actions altogether, as shown by the following lemma.

Lemma 10. *Under Scenario 1 of Lemma 1, Design 2 is attained for $B \geq F_0$ and $P_2^B = (1-pq)B$.*

Proof. For Design 2 to be feasible, conditions $\Pi_2^B > \Pi_0^B$ and $\Pi_2^B > \Pi_1^B$ must be true. As seen in previous proofs, this is equivalent to $B > F_0$ and $B > \frac{R'-(1-q)R}{q} - D$, respectively. Because $F_0 > \frac{R'-(1-q)R}{q} - D$ from Assumption 2, we can conclude the lower bound on B is F_0. □

From the above results, for subordinated debt only Design 0 and 2 are feasible. Hence, the related banker's program becomes

$$\max_{(i,B)} \left\{ \Pi_i^B(B) - K_i^D(B), \text{ subject to } K_i^D(B) \leq 0 \right\},$$

with the additional feasibility constraints for each design.

Lemma 11. *Under Scenario 1 of Lemma 1, with debt financing, the optimal value to the banker in each design is*

$$\mathcal{E}_0^D = R - 1 \textit{ for } B > 1 - D \textit{ and } B \in [0, F_0],$$

$$\mathcal{E}_2^D = (1-pq)R - 1 + pqD + G \textit{ for } B > \frac{1-D}{1-pq} \textit{ and } B \in [F_0, R-D].$$

Proof. Similar to the proof of Lemma 5, Design 0 delivers $\mathcal{E}_0^D = R-1$ if $1-D < F_0$, that is equivalent to $R-1 > \frac{G}{pq}$, which is Assumption 8. Design 2 has the same value as CoCo bonds in the same design, $\mathcal{E}_2^D = (1-pq)R-1+pqD+G$, and for this value to be achieved, condition $\frac{1-D}{1-pq} < R-D$ must hold true. That is equivalent to $(1-pq)R-1+pqD > 0$ from Assumption 6. □

To determine the optimal design under subordinate debt, we observe that $\mathcal{E}_0^D > \mathcal{E}_2^D$ is equivalent to $R-D > \frac{G}{pq}$, which is $F_0 > 0$. Under Scenario 1 of Lemma 1, $F_0 > F_2 > 0$. Hence, when both design are possible, Design 0 dominates 2. Given Design 0 is feasible for $B < F_0$ and Design 2 for $B > F_0$, then we have proved the following lemma.

Lemma 12. *Under Scenario 1 of Lemma 1,*

- *for $B \in [0, F_0]$ such that the budget condition $B > 1-D$ is satisfied, Design 0 is optimal;*
- *for $B \in [F_0, R-D]$ such that the constraint $B > \frac{1-D}{1-pq}$ is satisfied, Design 2 is optimal.*

Finally, the optimality of contract vis-à-vis the price of the security, and therefore the raised amount, is stated in the following proposition. Because we will be comparing subordinated debt to CoCo bond, we derive the result under the same assumptions of $F_1 < 0$ and $\frac{G}{pq} > p(R-R')$.

Proposition 2. *Under Scenario 1 of Lemma 1, for $F_1 < 0$ and assuming $\frac{G}{pq} > p(R-R')$, the banker's value as a function of the amount raised by issuing subordinated debt is*

- *if $\frac{G}{pq} > pq(R-D)$,*

$$\mathcal{E}^D(P) = \begin{cases} R-1 & \text{if } P^B \in [1-D, R-D-\frac{G}{pq}[\\ (1-pq)R-1+pqD+G & \text{if } P^B \in [R-D-\frac{G}{pq}, (1-pq)(R-D)] \end{cases}$$

- *if $\frac{G}{pq} \leq pq(R-D)$, $\mathcal{E}^D(P) = R-1$ if $P^B \in [1-D, R-D-\frac{G}{pq}[$.*

Proof. The break-even price of debt is

$$P^B = \begin{cases} B, & \text{if } B \in [1-D, F_0], \\ (1-pq)B, & \text{if } B \in]F_0, R-D]. \end{cases}$$

P^B is monotonically increasing in B, so we need to calculate the amounts at the boundaries of each interval. For the interval where Design 0 is optimal, the raised amount is B, that is $P^B \in [1-D, F_0]$. For the interval where Design 2 is optimal, $P^B(F_0) = (1-pq)F_0$ and $P^B(R-D) = (1-pq)(R-D)$.

The maximum amount raised using Design 2 is higher than that using Design 0 if $(1-pq)(R-D) > (R-D-\frac{G}{pq})$, that is $\frac{G}{pq} > pq(R-D)$. Because we are assuming $\frac{G}{pq} > p(R-R')$ and $F_1 < 0$ is equivalent to $pq(R-D) > p(R-R')$, we must consider two possible scenarios: (1) $\frac{G}{pq} > pq(R-D) > p(R-R')$; and (2) $pq(R-D) \geq \frac{G}{pq} > p(R-R')$.

In first scenario, in the interval $[(1-pq)F_0, F_0]$, Designs 0 and 2 may raise the same amount, but the banker chooses Design 0 because $\mathcal{E}_0^D > \mathcal{E}_2^D$. On the other hand, Design 2 is used to raise capital in $]F_0, (1-pq)(R-D)]$ and the banker's value is $\mathcal{E}_2^D$.

In the second scenario, Design 2 is dominated and the banker chooses Design 0 in the range $[1-D, (1-pq)(R-D)]$, but it only delivers a positive value to the banker for $P^B \in](1-pq)(R-D), F_0[$. Overall, in this scenario the banker can only fund the project using Design 0 and for $P^B \in [1-D, F_0[$. □

The comparison between CoCo bonds and subordinated debt is in Figure 10. The figure shows that the safe designs with both subordinated debt (blue) and CoCo bonds (black) is optimal if the principal is lower than $R-D-\frac{G}{pq}$, which is affordable by a well capitalized bank. In Panel A, if more capital must be raised by issuing the security, that is $P > R-D-\frac{G}{pq}$, subordinated debt fails to prevent any moral hazard actions and delivers $(1-pq)R-1+pqD+G$, which is lower than the value attainable with the CoCo bond. Indeed, from Lemma 7, we know that under condition $F_1 < 0$, and if

$$\frac{1-D+p[R-R'-q(R-D)]}{1-pq} > R-D-\frac{G}{pq}$$

the value of the CoCo bond is higher because it prevents risk-shifting. Finally, the CoCo bond makes it possible to invest in the project also if the banker has lower capitalization than if subordinated debt is used. In fact, with subordinated debt there is an upper bound to the amount raised, which is lower than the maximum amount that can be financed using CoCo bonds. This is because

$$R-D-p(R-R') > (1-pq)(R-D) \quad \Leftrightarrow \quad p(qR-qD-R+R') > 0,$$

if $F_1 < 0$.

Panel B presents the case $\frac{G}{pq} \leq pq(R-D)$, with a relatively low private benefit. An undercapitalized banker, who needs to raise more than $R-D-\frac{G}{pq}$, cannot do it using subordinated debt. Hence, issuing CoCo bonds is the only financing channel for those banks. The following proposition summarizes the result.

Proposition 3. *Under Scenario 1 of Lemma 1, and for $F_1 < 0$, subordinated debt is dominated by non-dilutive CoCos.*

Panel A: $\frac{G}{pq} > pq(R - D)$

Panel B: $p(R - R') < \frac{G}{pq} \leq pq(R - D)$

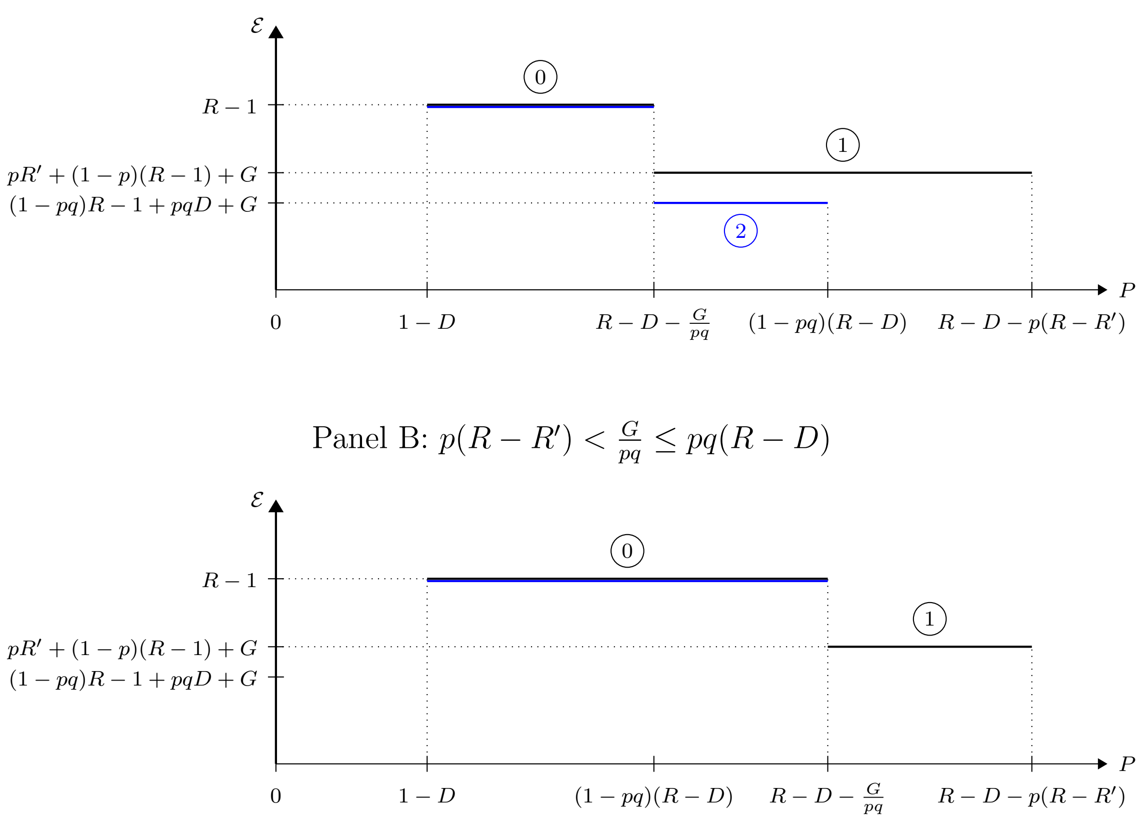


Figure 10: Optimal value to the banker against the amount raised by issuing the security, for $F_1 < 0$ and assuming $\frac{G}{pq} > p(R - R')$: CoCo bonds (black) vs subordinated debt (blue).

The key finding is that not only a non-dilutive CoCo is not dominated by junior debt, but for high financing needs it is dominant, as it can avoid ex post moral hazard. Moreover, there exists a value of P where CoCo is the only contract that can provide financing. That is, banks with a sufficiently large financing gap may only afford CoCo contracts. Moreover, CoCo delivers generally a higher value to the banker than subordinated debt.

4.2 Non-voting shares

With equity financing, the design parameter is the fraction α of the payoff given to outside equity holders. We focus on non-voting shares because the new equity holders will not be given any rights on the private benefit from shirking, G. The expected payoffs to the banker with equity financing are

$$\Pi_0^S = (1-\alpha)(R-D),$$

$$\Pi_1^S = (1-\alpha)[(1-p)(R-D) + p(R'-D)] + G,$$

and

$$\Pi_2^S = (1-\alpha)(1-pq)(R-D) + G.$$

The following discussion will be based on two thresholds for α:

$$\alpha_0 = 1 - \frac{G}{p(R-R')}, \qquad \alpha_1 = 1 - \frac{G}{pq(R-D)}.$$

We have the following preliminary results on equity financing.

Lemma 13. *Under Scenario 1 of Lemma 1, and for $F_1 < 0$, Design 0 is attained for $\alpha < \alpha_0$ and $P_0^S = \alpha(R-D)$.*

Proof. The first best choice results if both conditions $\Pi_0^S > \Pi_1^S$ and $\Pi_0^S > \Pi_2^S$ holds, which are equivalent to $\alpha < \alpha_0$ and $\alpha < \alpha_1$, respectively. Overall, the conditions require $\alpha < \min\{\alpha_0, \alpha_1\}$. Because

$$\alpha_0 < \alpha_1 \quad \Leftrightarrow \quad \frac{G[(1-q)R - R' + qD]}{pq(R-D)(R-R')} < 0,$$

and observing that $(1-q)R - R' + qD < 0$ is equivalent to $F_1 < 0$, then Design 0 is feasible for $\alpha < \alpha_0$. □

Lemma 14. *Under Scenario 1 of Lemma 1, and for $F_1 < 0$, Design 1 is attained for $\alpha \geq \alpha_0$ and $P_1^S = \alpha[R - D - p(R-R')]$.*

Proof. The conditions for Design 1 are $\Pi_1^S \geq \Pi_0^S$ and $\Pi_1^S \geq \Pi_2^S$. As showed before, the first condition is equivalent to $\alpha \geq \alpha_0$. The second condition does not impose any restriction on α, because it is gives $R' - D - (1-q)(R-D) > 0$, which is equivalent to $F_1 < 0$. □

Lemma 15. *Under Scenario 1 of Lemma 1, and for $F_1 < 0$, Design 2 is infeasible.*

Proof. For Design 2 to be feasible, it should be $\Pi_2^S > \Pi_0^S$ and $\Pi_2^S > \Pi_1^S$. However, we have shown that the first is equivalent to $\alpha > \alpha_1$ and the second is never true for $F_1 < 0$. □

From the analysis above, for the banker's program using equity financing, only Design 0 and 1 are available:

$$\max_{(i,\alpha)} \left\{ \Pi_i^S(\alpha) - K_i^S(\alpha), \text{ subject to } K_i^S(\alpha) \leq 0 \right\}$$

with the feasibility constraints specific for each design.

Lemma 16. *With equity financing, under Scenario 1 of Lemma 1, and for $F_1 < 0$, the optimal values to the banker in each design is*

$$\mathcal{E}_S^0 = R - 1 \text{ for } \alpha > \frac{1-D}{R-D} \text{ and } \alpha \in [0, \alpha_0[,$$

$$\mathcal{E}_S^1 = R - 1 + G - p(R - R') \text{ for } \alpha > \frac{1-D}{R - D - p(R-R')} \text{ and } \alpha \in [\alpha_0, 1].$$

Proof. With reference to Lemma 6, the optimal value in Design 0 is $\mathcal{E}_0^S = R - 1$, which is achievable if $\frac{1-D}{R-D} < \alpha_0$, that is $R - 1 > \frac{(R-D)G}{p(R-R')}$. If this condition is violated, Design 0 generates zero value to the banker. Design 1 generates a value of $R - 1 + G - p(R - R')$ if $\frac{1-D}{R-D-p(R-R')} < 1$, that is $(1-p)R + pR' > 1$, which is always satisfied under Assumption 3. □

Lemma 16 shows that two separate cases should be considered, depending on whether $R-1 > \frac{(R-D)G}{p(R-R')}$, for which Design 0 delivers $R-1$, or $R-1 \leq \frac{(R-D)G}{p(R-R')}$, for which Design 0 has zero value for the banker. This is summarized in the following lemma.

Lemma 17. *Under Scenario 1 of Lemma 1, and for $F_1 < 0$,*

1. *if $R - 1 > \frac{(R-D)G}{p(R-R')}$,*
   - *for $\alpha \in [0, \alpha_0[$ such that the budget condition $\alpha > \frac{1-D}{R-D}$, Design 0 is optimal;*
   - *for $\alpha \in [\alpha_0, 1]$ such that condition $\alpha > \frac{1-D}{R-D-p(R-R')}$, Design 1 is optimal.*

2. *if* $R-1 \leq \frac{(R-D)G}{p(R-R')}$,

   - *for* $\alpha \in [\alpha_0, 1]$ *such that condition* $\alpha > \frac{1-D}{R-D-p(R-R')}$, *Design 1 is optimal.*

We finally state the optimality of using non-voting share to finance the project as a function of the capital raised from outside.

Proposition 4. *Under Scenario 1 of Lemma 1, and for* $F_1 < 0$ *and* $\frac{G}{pq} > p(R-R')$,

1. *if* $R-1 > \frac{(R-D)G}{p(R-R')}$,

$$\mathcal{E}^S(P) = \begin{cases} R-1 & \text{if } P^S \in [1-D, R-D-\frac{R-D}{p(R-R')}G[\\ pR' + (1-p)R - 1 + G & \text{if } P^S \in [R-D-\frac{R-D}{p(R-R')}G, R-D-p(R-R')] \end{cases}$$

2. *if* $R-1 \leq \frac{(R-D)G}{p(R-R')}$, $\mathcal{E}^S(P) = pR' + (1-p)R - 1 + G$ *if* $P^S \in [1-D, R-D-p(R-R')]$.

Proof. With reference to Lemma 17, Design 0 can be financed and delivers a positive banker's value in Case 1, where $R-1 > \frac{(R-D)G}{p(R-R')}$. Under the assumptions, the break-even price of equity issuance is

$$P^S = \begin{cases} \alpha(R-D), & \text{if } \alpha \in [\frac{1-D}{R-D}, \alpha_0[, \\ \alpha[R-D-p(R-R')], & \text{if } \alpha \in [\max\{\frac{1-D}{p(R'-R)+R-D}, \alpha_0\}, 1]. \end{cases}$$

P^S is monotonically increasing in α, so it suffices to calculate the value at the boundaries of the relevant intervals. Where Design 0 is optimal, the capital raised by the bank by issuing equity is $P^S(\frac{1-D}{R-D}) = 1-D$. The maximum amount with Design 0 is $P^S(\alpha_0) = R-D-\frac{R-D}{p(R-R')}G$.

For Design 1, the maximum amount is $P^S(1) = R-D-p(R-R')$, and it is always greater than the maximum amount from Design 0 under the assumptions of the proposition. This is because $F_1 < 0$, which is equivalent to $q(R-D) > (R-R')$, that is $\frac{R-D}{p(R-R')}G > \frac{G}{pq}$. Also, $\frac{G}{pq} > p(R-R')$ by assumption. Hence, for the maximum amounts under the two designs, $R-D-p(R-R') > R-D-\frac{R-D}{p(R-R')}G$, that is $\frac{R-D}{p(R-R')}G > p(R-R')$. But this exactly what the two assumptions imply.

As for the minimum amount, if $\frac{1-D}{p(R'-R)+R-D} > \alpha_0$, the minimum security price is $P^S(\frac{1-D}{p(R'-R)+R-D}) = 1-D$. Otherwise, if $\frac{1-D}{p(R'-R)+R-D} < \alpha_0$, it is

$$P^S(\alpha_0) = R-D-\frac{R-D}{p(R-R')}G - p(R-R') + G.$$

The minimum amount raised by Design 1 is lower than the maximum amount raised by Design 0, because $1 - D < R - D - \frac{R-D}{p(R-R')}G$, and

$$R - D - \frac{R-D}{p(R-R')}G - p(R-R') + G < R - D - \frac{R-D}{p(R-R')}G.$$

As $\mathcal{E}_S^0 > \mathcal{E}_S^1$, the banker chooses Design 0 over Design 1 when both are feasible. Namely, Design 1 is optimal only if $P \in]R - D - \frac{R-D}{p(R-R')}G, R - D - p(R-R')]$.

In Case 2, Design 0 gives zero value to the banker. Consequently, the banker can only issue non-voting shares under Design 1. This case is defined by $\alpha_0 \leq \frac{1-D}{R-D}$, and because $\frac{1-D}{R-D} < \frac{1-D}{p(R'-R)+R-D}$, then $\alpha_0 < \frac{1-D}{p(R'-R)+R-D}$. Therefore, the minimum security price of Design 1 is $P^S(\frac{1-D}{p(R'-R)+R-D}) = 1 - D$. Overall, Design 1 is optimal and delivers $\mathcal{E}_S^1$ if $P \in [1 - D, R - D - p(R-R')]$. □

Finally, we compare CoCo bonds to non-voting shares in Figure 11, which shows that the maximum amounts that can be raised from CoCo bonds (black) and non-voting shares (red) are the same. As we focus on the case $F_1 < 0$, neither of them encourages the banker to shift risks. In Panel A, for $R - 1 > \frac{(R-D)G}{p(R-R')}$, for designs that achieve first best, the banker raises more capital by issuing CoCo bonds. In particular, for $P \in [R - D - \frac{R-D}{p(R-R')}G, R - D - \frac{G}{pq}[$, non-voting shares fail to avoid the shirking action and deliver an inferior value to the banker, $pR' + (1-p)(R-1) + G$, while the safe design with CoCo achieves $R - 1$. If the amount of capital raised from outside is higher than $R - D - \frac{G}{pq}$, CoCo bond are not dominated. Panel B displays the case with $R - 1 \leq \frac{(R-D)G}{p(R-R')}$ where the safe design with non-voting shares is never affordable and Design 1 is the only option. For $P \in [1-D, R-D-\frac{G}{pq}[$ Design 0 can be implemented with CoCo bonds and it generates a higher banker's value than non-voting shares. For higher external financing needs, CoCo bonds are not dominated. The following proposition summarizes the result.

Proposition 5. *Under Scenario 1 of Lemma 1, and for $F_1 < 0$, non-votings share are weakly dominated by CoCos.*

The intuition of the result is that CoCo bonds are better than non-voting shares at mitigating both moral hazard problems, because equity inflexibly allocates a fixed fraction of wealth to outsider financiers, independently of the outcome. If the design is meant to avoid shirking, the banker should keep a large fraction to compensate the loss of private benefit, which leads to less pledgeable income for outside financiers. Differently from non-voting shares, the CoCo bond is less rigid as it allows to tune the contract to the outcome, using the face value, F, and the conversion fraction, λ. In other words, a CoCo bond allows the banker to keeps the upside in the good state and a small fraction of wealth upon conversion in a bad state. The latter not only corrects ex-ante incentives

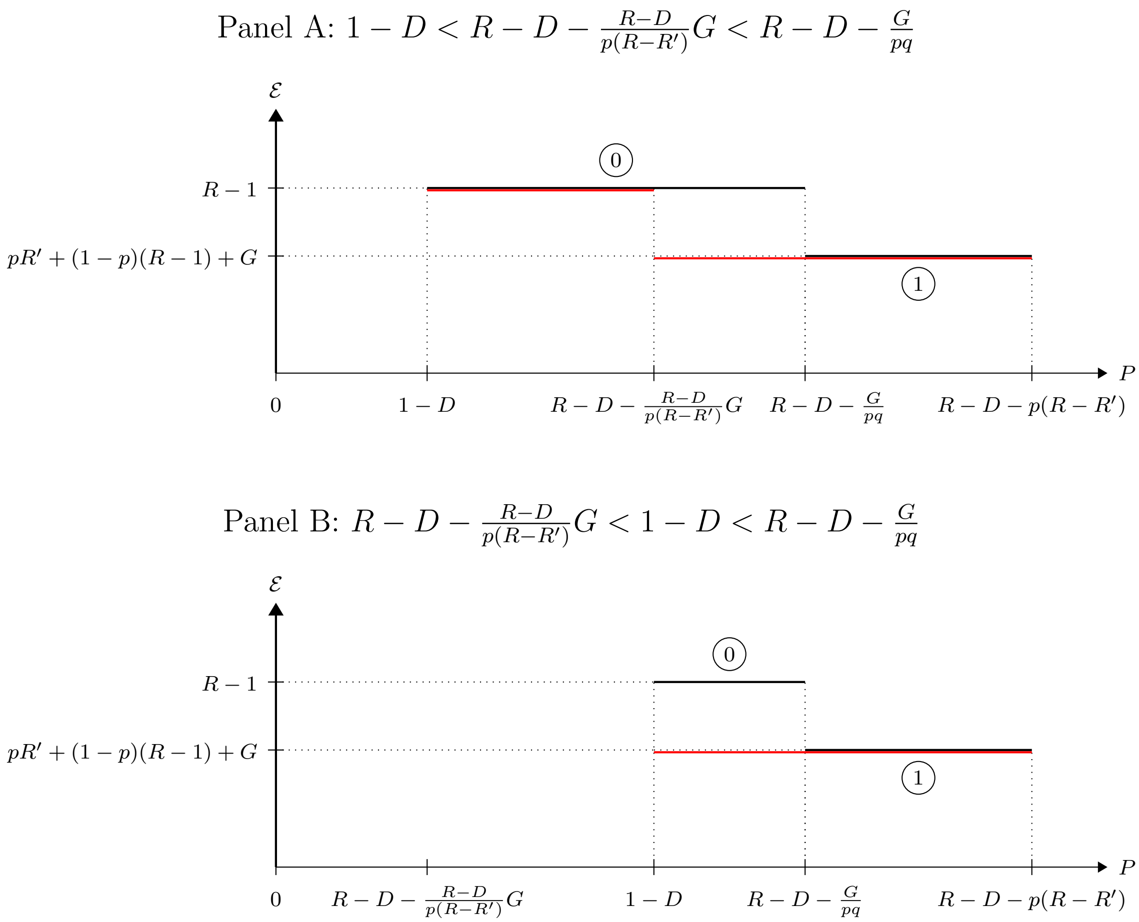


Figure 11: Optimal value to the banker against the amount raised by issuing the security: CoCo bonds (black) vs non-voting shares (red).

but also leaves a higher pledgeable income. Remarkably, there are values of P for which CoCo bond is the only optimal contract that can be used by the banker in our setup.

5 Empirical analysis

In this section, we test the main conclusions from our theory using empirical data. Because CoCo bonds became popular just after the last financial crisis, empirical studies in this area are limited. So far, the empirical literature has been focussing on the determinants of CoCo issuances. **?** show, in emerging economies, that banks with higher regulatory capital ratios and lower loan levels are more likely to issue CoCo bonds. In Europe (in particular, the European Economic Area), **?** find that CoCos are more attractive for riskier banks. This result is also supported by **?**, who use global data and find that most of CoCo issuances was done by banks characterized by high systematic risk. The common denominator of these studies is that is larger banks, which are likely to have a stronger exposure to market risk, tend to be the main issuers of CoCos.

Different from those contributions, the hypotheses built on our theory focus on the post-CoCo issuance behavior of a bank. Only few papers test empirically whether the risk-taking behavior of CoCo issuers is different from the one of non-issuers, and they provide mixed results regarding how CoCo bonds impact the volatility of bank assets. **?** and **?** focus on the pricing side of CoCo bonds and show that CoCo investors seem to be aware of the fact that CoCos exacerbates agency problems. Our empirical analysis allows us to analyze how the inclusion of CoCo bonds in banks' capital structure affects their risk appetite, that is how CoCos affect banks' agency problems.

More recently, **?** perform a duration analysis to analyze the determinants of the decision to issue CoCos and estimate the changes in a bank's credit risk (measured by the CDS spread) after CoCo issuance. In particular, they focus on the impacts of two different types of CoCo bonds: principal write-down (PWD) and equity conversion. They find that equity conversion CoCo bonds significantly reduce a bank' CDS spread, whereas PWD CoCos have a weaker and not statistically significant effect on the CDS spread. Since the conversion mechanism of both types of CoCo allow for loss absorption (and PWD CoCo do so to a greater extent), they should both negatively impact CDS spreads, if the risk-taking incentive of the bank remains unaffected. The authors conclude that, if the overall effect is not statistically different from zero, then the risk-taking incentives must increase after the issuance of PWD CoCo bonds, offsetting the positive effect of loss absorption on banks' credit worthiness. **?** also use CDS spreads to test the effect of CoCo issuance announcement on bank default risk. However, their results show that PWD CoCo bonds outperform equity-conversion CoCo bonds, and on average, PWD CoCo bonds reduce default risk in a similar fashion as common equity.

The challenge or all these empirical studies is that it is hard to separate the two offsetting effects of CoCo issuance on CDS spreads: negative on the credit worthiness of the bank due to the improved regulatory capital, and positive on the risk of the banks' investments due to change of risk-taking incentives. We address this challenge by focussing directly on the effect of CoCo issuance on the risk appetite of the bank, rather that on its credit worthiness. To do this, we use loan spreads from the syndicated loan market. Because syndicate loans allow firms to borrow from multiple banks, they give us a way to compare the risk-taking behavior of different banks when lending to the same borrower, which enable us to use the cross-sectional difference among banks in the face of the same investment risk. To be specific, since multiple lenders participate in one syndicated loan package, the financing needs of any individual firm can be stably supplied without the concern of the change in lending policies of a specific lender. This allows to control for the demand of funding over the time. We can then investigate how the risk appetite of a bank changes regarding its lending activity in the syndicated loan market by comparing the loan spreads for CoCo issuers vs non-issuers. Overall, our empirical approach can address how asset risk in a bank is impacted by CoCo issuance, which helps the identification of the risk-taking incentives.

5.1 Data and summary statistics

The analysis uses multiple data sources. First, the data on CoCo issuances is collected from Bloomberg, from which we have that a total of 851 CoCos issuances occurred from 2009 to 2019. Our analysis focuses on the risk-taking behavior associated with bail-in CoCo bonds. For this reason, we choose to focus only on global systemically important banks (G-SIBs) because they are strictly regulated and have stronger incentives to issue a security, like a CoCo bond, which gives regulatory benefit to comply with Basel III while financing the increased capital ratio.

Due to different requirements, a CoCo bond could be classified as either Tier 1 (AT1) or Tier 2 capital.[14] Only AT1 CoCo bonds are assumed to be 'bail-in' securities. From the Pillar 3 reports, we exclude ineligible AT1 CoCo bonds, which leaves us with 190 CoCo issuance over the sample period, for a total of 25 G-SIBs represented. In our sample, the earliest AT1 CoCo issuance occurred in 2013, following with the update of regulation. Within those G-SIBs, we find that most banks have never issued any equity-conversion CoCo bonds and instead focused on PWD CoCo bonds. In Table 2, we collected all the CoCo issuances by G-SIBs.

A CoCo bond is non-dilutive if its holder receives a lower amount than the principle value upon conversion. CoCos with a lower conversion price than the stock price at the

[14]The key difference between Tier 1 and 2 CoCos is the going-concern contingent capital requirement. Under Basel III, the minimum trigger level (in terms of CET1/RWA) required for a CoCo to qualify as AT1 capital is 5.125%.

conversion date benefit the holder. In this case, the conversion ratio γ in equation (2) is greater than 1 and the CoCo bond is dilutive for the incumbent shareholders. In contrast, if the stock price is lower than the conversion price, that is $\gamma < 1$, the conversion event is non-dilutive for the shareholders. In the context of our model, Design 1 CoCo bonds are equity-conversion CoCos of this second type, with high conversion prices vis-à-vis the stock prices. The extreme case of PWD CoCos correspond to the case $\gamma = 0$.

Table 2 shows that the CoCos issued so far are predominantly non-dilutive, which is puzzling given the theoretical literature criticizes their ability to stabilize the financial system. From Panel B in Table 2, only one bank from non-UK countries issued equity-conversion CoCo bonds, while all the other banks only issued PWD CoCos, which are the most non-dilutive for incumbent equity holders. In the UK, although G-SIBs did not issue PWD CoCos, the conversion price is significantly higher than the stock price at the beginning of the COVID pandemic to make them highly non-dilutive for the shareholders.

Second, we need data related to the syndicated loan market, which is a very important market for worldwide corporate financing (**?**). The data source of syndicated loans is Reuters' DealScan database. Indeed, almost all loans in DealScan are syndicated loans. The advantage of using data from this market is that a firm borrows from a group of lenders. Even if some of the lenders change their lending behavior, the firm could still get financed from the rest of the syndicate. Therefore the syndicated loan market is attractive and provide a stable supply of funding for firms. More importantly, loan spreads are different across different facilities within the same loan package taken by a firm. That is, banks participating in the same package do not necessarily share the same pricing strategy, but may have differentiated ones, which arguably reflect their risk-attitude.

A drawback of using syndicated loan market data is that on average two-thirds of banks' share of volumes for each loan facility are not all recorded, which limits the extent of our investigation regarding the total volume of loans a bank lends every year. Besides, we keep only syndicated loans with recorded facility amounts, because a larger facility size shows that the borrower has a higher leverage ratio and higher default risk. As banks would charge a higher spread in this case, we use the facility amount to control for the overall risk of the borrower.

We aim at tracking the pricing strategy of banks to measure how much a bank asks for compensating the risk it bears. Therefore, we use loan spreads, which are available from DealScan, to capture the pricing difference. We end up with 88,554 loan facilities with at least one G-SIBs in the syndicate in the period from 2007 to 2019.

As for the contracting date, we use the deal active date because it is usually the start date of the first facility among all the facilities within the same package. **?** reports that it could take a bank more than three months to approve a term sheet, and therefore he

Table 2: Active CoCos from G-SIBs

This table shows the type of AT1 CoCos issued by G-SIBs from 2013 to 2019. Panel A reports CoCos from UK banks and Panel B from non-UK banks. For UK banks, the conversion price is collected from the terms of the CoCo contracts and stock price is recorded at the opening of April 20, 2020. For PWD CoCos the conversion prices are not shown in contracts, and stock prices are not needed for comparison.

(a) Panel A: UK banks

Parent	Active CoCos	Weight in Tier 1 capital	PWD	Conversion Price	Stock Price.
HSBC	13	13.59%	N	£2.70	£4.16
Barclays	11	19.57%	N	£1.65	£0.91
Lloyds	7	17.37%	N	£0.63	£0.31
RBS	3	11.32%	N	$2.28	$1.33
SC PLC	4	12.80%	N	£5.96	£4.09
Subsidiary	Active CoCos	Weight in Tier 1 capital	PWD	Conversion Price	Stock Price.
HSBC bank	5	19.16%	Y	-	-
Lloyds bank	7	16.36%	Y	-	-
Natwest Holdings	2	14.67%	Y	-	-

(b) Panel B: Non-UK banks

Parent	Active CoCos	Weight in Tier 1 capital	PWD	Conversion Price	Stock Price.
BoC	1	2.20%	Y	-	-
BNP Paribas	8	7.66%	Y	-	-
Deutsche Bank AG	4	10.57%	Y	-	-
ICBC	1	3.01%	Y	-	-
CCB	1	1.81%	Y	-	-
Agricultural Bank of China	1	6.18%	Y	-	-
Credit Suisse Group	7	17.81%	Y	-	-
Groupe BPCE	0	0	-	-	-
Groupe Crédit Agricole	4	4.02%	Y	-	-
ING Group	5	12.15%	N	Unknown	-
Mizuho FG	9	19.35%	Y	-	-
Santander	4	17.16%	Y	-	-
Société Générale	9	18.35%	Y	-	-
SM FG	6	6.22%	Y	-	-
UBS Group	13	31.53%	Y	-	-
Unicredit Group	4	6.58%	Y	-	-

sets the contracting date as 90 days prior to the start date. We adopt his approach in our robustness checks.

Third, we use bank-level information taken from Bureau van Dijk's BankFocus, which provides balance sheet information and regulatory variables for banks. We focus on 33 banks that are or have been G-SIBs. The list of G-SIBs is in Table 6 in Appendix C. We choose Moody's Investors Service as the accounting sub-template, which provides comprehensive data for most banks from 2010 to 2019 (except for UBS, which is missing after 2018, and therefore the last two years for UBS are dropped from the sample). We use consolidated data to capture the accounting performance of the banks.[15] We set years 2010-2011 in the sample to be the pre-regulation period and 2012-2019 the post-regulation period. We exclude 2011 from the post-regulation period because the release of **?** happened in October 2011, and no AT1 CoCo bonds were issued before 2013, which shows it took time for banks to adopt the new regulatory change.

We match the data across the three database and report the summary statistics of the final sample in Table 3. For loan characteristics, we use All-in-drawn spread as the measure of lending risk. As defined by DealScan, the All-in-drawn spread (in basis points) is the incremental interest rate the borrower pays over LIBOR, and it includes fixed and upfront fees and variable credit spread that the borrower pays for each dollar drawn down under the loan commitment. In the sample All-in-drawn spreads have outliers and the maximum and minimum values are 2000 and 1.75 basis points respectively. After checking the facilities from the same borrowers in the same or adjacent years, we conclude that those outliers are caused by recording errors. Thus, we drop all observations in the first and last percentile and report the results in Table 3, which shows that the remaining All-in-drawn spreads still present a reasonable variation.

5.2 Empirical strategy

Our theory predicts that non-dilutive CoCos reduce the risk-shifting incentives of an undercapitalized bank. Therefore, banks replacing subordinated debt with CoCo bonds in the capital structure should have a reduced risk appetite, everything else equal.

Our empirical analysis is designed to check the changes in lending strategies of banks after the CoCo issuance. We construct a Diff-in-Diff (DiD) estimator for which the event is a bank's first CoCo issuance. A baseline model is regressed, where the treated banks are those which issued CoCo bonds during the sample period. This regression aims at directly tracking changes in banks' risk appetite after including CoCo bonds in their capital structure. The risk appetite in our analysis is gauged by the loan spreads that a bank charges to a specific borrower. Based on the model, we predict that banks which

[15] In Bankscope, We collect indexes with C^* consolidation code.

Table 3: Summary Statistics

Descriptive statistics for the merged sample from three sources: (1) syndicated loans lent by G-SIBs from 2010 to 2019, (2) bank characteristics, lagged accounting and regulatory variables of G-SIBs from 2009 to 2018, (3) CoCo issuance occurred from 2009 to 2019.

	N	mean	sd	min	max	p1	p5	p10	p90	p95	p99
Loan characteristics											
All-In-Drawn (bps)	83,028	244.0	144.3	28	825	45	75	100	450	500	725
Facility amount (million $)	83,028	929.6	1,706	0.000820	48,501	6.318	29.13	57.99	2,150	3,323	7,500
Bank characteristics											
Total Assets (million $)	83,028	1,632	692.8	156.8	4,042	274.1	749.9	806.9	2,558	2,693	3,103
Equity/Total Assets (%)	83,028	6.964	2.690	2.526	12.89	2.530	3.411	3.864	10.99	11.27	12.62
Total Equity (million $)	83,028	114.5	70.01	13.74	341.2	20.38	41.64	45.38	214.0	243.5	267.1
Quick Ratio (%)	83,028	42.17	12.52	19.93	78.72	23.52	27.08	28.86	59.59	71.68	77.00
Deposits and Short-term Funding (million $)	83,028	951.9	513.0	120.9	3,514	222.3	268.9	422.4	1,501	1,672	2,668
Customer Deposits (million $)	83,028	772.3	460.3	39.34	3,124	63.81	156.0	305.9	1,340	1,382	2,216
Net Income (million $)	83,028	7.962	9.216	-18.73	45.15	-9.162	-3.044	-1.543	22.22	23.61	29.66
Tier 1 ratio (%)	83,028	13.29	2.090	7.740	22.30	9.250	9.970	10.90	16.10	16.98	19.30

have issued CoCo bonds tighten their lending activities by charging a higher spreads, everything else equal.

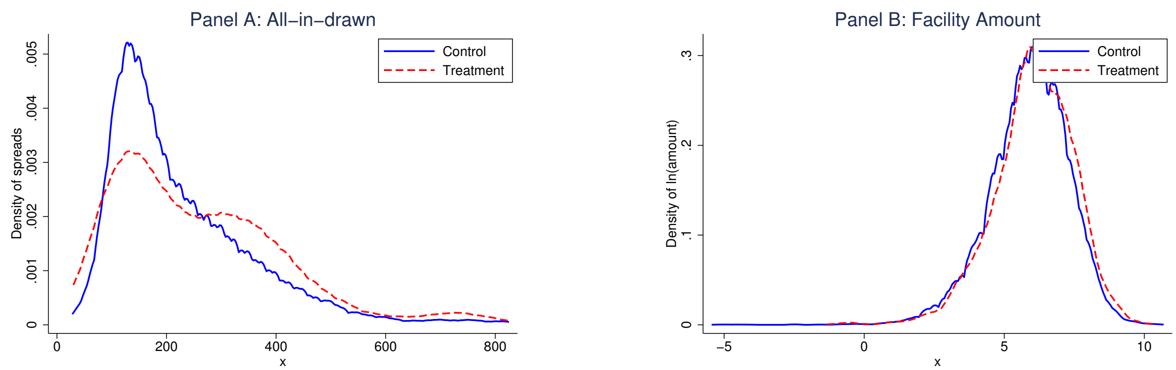
Loan spreads change due to both demand- and supply-side effects in the loan market. Our test concentrates on the lending strategies of fund-suppliers, so the demand of funds must be controlled for. Our methodology follows **?** and **?**, who control for the loan demand and bank characteristics. Moreover, we assume the loan demand for each borrower is constant within one year so that we use borrower-year fixed effect to control for the time-varying loan demands for each firm and the cross section of firms.

We are upfront on the fact that a tightened lending strategy can result in both a reduction in loan volumes and an increase in loan spreads, the two being not mutually exclusive. In other words, a more "risk averse" bank invests less into risky loans and asks for a higher return to compensate the risk. However, as we mentioned before, DealScan data is not sufficient to perform a loan volume analysis, because of the large number of missing values of individual banks' portion of a given loan facility. We therefore focus the test on loan spreads only. In this respect, the pricing heterogeneity under the same package allows us to track the risk appetite of a bank.

In the DiD method, the parallel trends assumption requires that both treatment and control groups behave similarly before the event. However, that cannot be directly checked in our setup, because each bank has a different event date. If all banks started issuing CoCos at the date the new regulation was released we would use the same event date for all of them. Instead, banks made their own choice as for the adoption of CoCo bonds. For this reason, we have to check the robustness of our result using an alternative approach, in which the pre-event period of the treatment group is set to be one year

Figure 12: Pre-event density of All-in-drawn spreads.

This figure compares the characteristics of the loans of the control group vs. the treatment group before the event. Panel A shows the density of All-in-drawn spreads (in basis points), Panel B the density of the natural logarithm of the loaned amounts.



before the first CoCo issuance for a bank. In what follows, we compare the lending behavior of the treated banks in the pre-event year with the controlled banks' lending activity over the whole sample period.

The characteristics of the loans observed before the event in the treatment group are compared to those of the loans in the control group. In Figure 12, Panel A shows the density of All-in-drawn spreads, Panel B the density of the amounts of the participated facilities. The comparison shows a similar lending behavior for the banks in the two groups, as they originate loans in a similar spread range and with similar distribution and average (around 180 basis points). Also, both treatment and control group of banks are similar as per the amount of lended capital of the participated loan. Because the pre-event lending strategies of banks in the treatment and the control group are similar, the DiD approach captures the change in lending behavior related to the first issuance of CoCos.

Our baseline specification is

$$Spread_{i,b,l,t} = \alpha_{b,t} + \beta_0 Treat_l + \beta_1 DiD_{l,t-1} + \gamma_1 X_{l,t-1} + \gamma_2 Y_{i,t} + \epsilon_{i,b,l,t}, \tag{4}$$

with borrower-year fixed effects to control for the time-variant demand change. In (4), i is the index of loan facilities, b for borrower, l for lender; $\alpha_{b,t}$ is the borrower-year fixed effects, which controls the loan demands; $Treat_l$ is an indicator of the treatment group, which equals one if the bank is in a country where CoCo bonds qualifies as AT1 capital; $DiD_{l,t}$ is the interaction term between the treated banks and the first CoCo issuance, which equals one if the treated banks had issued at least one CoCo bond before the end of the year; $X_{l,t-1}$ is a vector of lagged controls given by bank characteristics; $Y_{i,t}$ is a vector of control given by loan characteristics. We estimate this model at loan level.

The coefficient β_1 gauges the change in the treated banks' risk-taking incentives due to CoCo issuance. We expect a negative correlation between the loan spreads and the bank's risk-appetite. The advantages of tracking the loan spreads directly is that banks set loan rates based on accessible information. Although the loan performance could be affected by shocks that not related to banks' risk preferences, focussing on the loan spreads isolates banks' risk-appetite at the contracting date.

5.3 Results

Table 4 provides the results of our analysis with the baseline model. Standard errors are clustered at the lender's level. The treatment group of the baseline model contains banks with at least one CoCo issuance during the sample period. Besides, loan demand and time-variant borrower characteristics are captured by the borrower-year fixed effect. The fixed effect model allows us to observe the difference in lending strategies when banks lend to an average firm. While the demand of loans are controlled for, a bank with a low risk appetite would choose to invest less and/or increase the loan spread.

The estimated coefficient β_1 demonstrates that CoCo issuers ask for a higher compensation for the credit risk of the borrower. Across all models, the coefficient of DiD is always positive, and in Models (1) to (5) it is significant at 5% level, which supports the hypothesis that the treated banks ask for a higher spread on loans after their first CoCo issuance. At the same time, the estimate of β_0, the coefficient of $Treat$, is never significant, which suggests that there is no significant difference between treatment and control groups before a CoCo issuance. Namely, they would charge a similar loan spread when they lend to the same borrower. However, after a CoCo issuance, the treated banks alter their pricing standard and demand higher returns, which support our theory that non-dilutive CoCo contribute to changing the risk attitude of banks, everything else equal.

Although some of the bank characteristics do not have a significant impact on pricing strategies, the coefficients of deposits and short-term funding, deposit ratio, and customer deposits are statistically significant and their negative sign supports our theory. That is, banks with higher level of deposits face more severe risk-shifting agency issues, so they tend to relax their lending standards and provide cheaper funds to the market, or equivalently, they require a lower premium in the face of the same credit risk. The negative relationship between those measures of bank leverage and the All-in-drawn spread suggest lenders with higher leverage charge lower loan spreads in the syndicated loan market.

We check the robustness of the baseline regression by using the contracting date as the active date of a facility, as opposed to the date the borrower starts using the facility. The contracting date is identified as 90 days prior to the facility start date in **?**. The

Table 4: Baseline model

This table reports the empirical test of the baseline Diff-in-Diff model. The dependent variable is the All-in-drawn spread required by the participant banks. The banks in the treatment group have issued at least one AT1 CoCo bond during the sample period from 2010 to 2019. The model evaluates the effects on the spread of the participated facilities by treated banks vis-à-vis the banks that never issued CoCo bonds. In Models (1), (4), (7) and (8), Facility size is natural logarithm of the loan amount. Except for Model (1), the other models control for bank characteristics: equity-to-asset ratio, deposits and short-term funding, customer deposits, net income, Bank size(the natural logarithm of a bank's total assets) and Deposit ratio(customer deposits over total assets). Standard errors are clustered at the lender's level.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DiD	1.408**	1.438**	1.640**	1.392**	1.252**	1.308*	1.214*	1.278*
	(2.344)	(2.358)	(2.154)	(2.324)	(2.107)	(1.966)	(1.914)	(1.962)
Treat	0.495	-0.359	-0.336	0.487	0.600	0.573	0.539	0.356
	(0.507)	(-0.346)	(-0.457)	(0.502)	(0.604)	(0.608)	(0.562)	(0.406)
Facility Size				1.596**			1.591**	1.589**
				(2.233)			(2.220)	(2.217)
Equity/Total Assets		-0.223			0.0223	0.0351	0.0271	
		(-1.036)			(0.121)	(0.211)	(0.152)	
Deposit Ratio			-6.388***					
			(-2.854)					
Bank Size					0.620	0.851	0.554	0.746
					(1.042)	(1.521)	(0.944)	(1.243)
Deposits and Short-term Funding					-0.00219**		-0.00197**	
					(-2.500)		(-2.199)	
Customer Deposits						-0.00309**		-0.00267**
						(-2.683)		(-2.317)
Net Income						0.0165	-0.0137	
						(0.344)	(-0.264)	
Constant	243.3***	245.3***	246.7***	233.8***	240.7***	239.1***	231.6***	230.6***
	(370.4)	(142.4)	(270.9)	(58.11)	(52.54)	(58.46)	(37.53)	(49.13)
Observations	83,028	83,028	83,028	83,028	83,028	83,028	83,028	83,028
R-squared	0.887	0.887	0.887	0.887	0.887	0.887	0.887	0.887
Borrower*Year FE	YES	YES	YES	YES	YES	YES	YES	YES

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

loan date could be crucial for analyzing banks' lending behavior in our analysis. As a direct consequence, the contracting date is no longer necessary to be the same for all the facilities in one package. On the demand side, the total amount of loans that each firm borrows in each year changes accordingly. Also, one may argue loan spread reveals the lenders' risk appetites at the time the loan is contracted, rather than when it is used. Therefore, using the contracting date should provide more accurate results, as the changed bank' risk appetite due to the adoption of CoCo should be more clearly reflected in the offered loan spreads.

The results in Table 5 delivers the same conclusion as the baseline model. The sign of the coefficient of DiD is confirmed and is statistically more significant than in the baseline analysis. With the borrower-year fixed effects, both suggest that, with CoCo bonds in the capital structure, banks on average charge a higher premium for the same borrower in the same year. On the other hand, banks that have more deposits tend to have a stronger risk preference by charging a lower premium on average. Overall, the robustness check confirms that our results are not driven by other events that happens between the contracting date and active date.

6 Conclusions

In this paper, we empirically document the prevalence of non-dilutive CoCos — practically all AT1 CoCos issued by G-SIBs are non-dilutive — despite the initial envisioning that CoCos need to be dilutive to penalize and deter bank shareholders' risk-taking. We further show that, although CoCos are non-dilutive in market practice, they are still associated with more prudent lending strategies of banks using loan-level data from the syndicated loan markets. To understand the prevalence of non-dilutive CoCos and the risk-taking incentives that they provide, we build an agency model with two subsequent moral hazard actions: a bank may (1) slack on its loan screening effort and (2) take on further risks to gamble for resurrection when the lack of screening already results in losses and will trigger CoCo conversion. We show that non-dilutive CoCos preserve shareholders' value after the bank has made losses and prevent gambling for resurrection. This, however, compromises the shareholders' incentives to properly screen loans in the first place. In other words, the answer to the question of how non-dilutive CoCos affect bank risk-taking can be subtle and state-contingent. In determining the dilutiveness of the hybrid security, one needs to strike a balance between preventing ex-ante and ex-post risk-taking.

We show that the design of CoCos can crucially depend on the equity capitalization of the bank. Since the non-dilutive CoCos tackle only the gambling for resurrection problem and therefore concede less rent to the management/owners of the bank, they generate more pledgeable income and relax the financing constraint for the bank. This

Table 5: Robustness check

This table reports the empirical test of the baseline Diff-in-Diff model. The difference from Table 4 is the starting date of each facility is the contracting date, following **?**. The dependent variable is the All-in-drawn spread required by the participant banks. The banks in the treatment group have issued at least one AT1 CoCo bond during the sample period from 2010 to 2019. The model evaluates the effects on the spread of the participated facilities by treated banks vis-à-vis the banks that never issued CoCo bonds. Except for Model (1), the other models control for bank characteristics: equity-to-asset ratio, deposits and short-term funding, customer deposits, net income, Bank size(the natural logarithm of a bank's total assets) and Deposit ratio(customer deposits over total assets). Standard errors are clustered at the lender's level.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DiD	1.464***	1.461***	1.652**	1.451***	1.371***	1.413**	1.272**	1.443**
	(2.901)	(2.893)	(2.682)	(2.884)	(2.775)	(2.374)	(2.159)	(2.652)
Treat	0.215	-0.325	-0.490	0.212	0.553	0.537	0.405	0.0156
	(0.238)	(-0.374)	(-0.803)	(0.236)	(0.576)	(0.575)	(0.423)	(0.0177)
Facility Size				1.226**			1.220**	1.218**
				(2.145)			(2.130)	(2.124)
Equity/Total Assets		-0.139			0.0826	0.134	0.0973	
		(-0.709)			(0.472)	(0.874)	(0.585)	
Deposit Ratio			-5.759***					
			(-2.852)					
Bank Size					0.606	0.906	0.411	0.887
					(1.033)	(1.680)	(0.718)	(1.439)
Deposits and Short-term Funding					-0.00187**		-0.00125	
					(-2.352)		(-1.465)	
Customer Deposits						-0.00267**		-0.00238**
						(-2.523)		(-2.248)
Net Income						-0.00658	-0.0410	
						(-0.142)	(-0.834)	
Constant	243.0***	244.3***	246.0***	235.7***	239.6***	237.4***	233.5***	231.2***
	(357.7)	(162.8)	(308.2)	(73.66)	(55.33)	(61.32)	(50.60)	(63.51)
Observations	84,220	84,220	84,220	84,220	84,220	84,220	84,220	84,220
R-squared	0.890	0.890	0.890	0.890	0.890	0.890	0.890	0.890
Borrower*Year FE	YES	YES	YES	YES	YES	YES	YES	YES

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

makes such CoCos particularly attractive to less-than-ideally capitalized banks, even though the only partially addressed risk-taking problem negatively affects the overall value of the bank. On the other hand, fully dilutive CoCos can be attainable when banks are better equity capitalized. Our model, therefore, shows that CoCos are no substitute for banks' equity capital, but rather the effectiveness of CoCos in preventing risk-taking depends on banks' equity capitalization. We also think that our theoretical prediction opens routes for new empirical research, e.g., how the designs of CoCos are related to banks' equity capitalization or the cost of equity.

Finally, from a policy point of view, we provide a somewhat moderating view in the debate of the usefulness and the regulatory treatment of CoCos. In light of the current market practices, we are not unrealistically optimistic that CoCos will automatically correct all risk-taking incentives with their dilutive features. But we are not entirely pessimistic and consider non-dilutive CoCos necessarily inducing risk-taking either because we do obtain empirical evidence that non-dilutive CoCos are still associated with more prudent lending strategies. Looking forward, we think more can be done for CoCos to fulfill their role in promoting financial stability fully, and whether that is attainable crucially depends on the equity capitalization of banks.

A Case with $F_1 \geq 0$.

The baseline model is focused on the case $F_1 < 0$, to emphasize the conversion mechanism of CoCo bonds. In this appendix, we derive an equivalent analysis on CoCo bonds, subordinate debt, and non-voting shares for the case $F_1 \geq 0$.

A.1 CoCo and subordinate debt

In the proof of Lemma 6, $\mathcal{E}_1^C > \mathcal{E}_2^C$ is equivalent to $R - D < \frac{R'-D}{1-q}$, which is violated if $F_1 \geq 0$. Thus, the 'necessary evil' CoCo design is no longer optimal for any F. The next lemma summarizes shows that Design 0 and Design 2 are the only two plausible CoCo designs in this alternative scenario.

Lemma 18. *Under Scenario 1 of Lemma 1, if $F_1 \geq 0$,*

- *for $F \in [F_2, F_0]$, such that the budget condition $F > 1 - D$ is satisfied, Design 0 is optimal;*
- *for $F \in]F_0, R - D]$ such that the budget condition $F > \frac{1-D}{1-pq}$ is satisfied, Design 2 is optimal.*

Proof. Lemma 7 shows that Design 0 dominates Design 1 for $F \in [F_2, F_0]$, independently of F_1. For $F \in [F_0, R - D]$, both Design 1 and Design 2 are feasible. But, as we proved before, $\mathcal{E}_2 > \mathcal{E}_1$ is equivalent to $R - D > \frac{R'-D}{1-q}$, which is equivalent to $F_1 > 0$. Besides, there is a higher threshold on F to achieve $\mathcal{E}_1^C$ for Design 1, as

$$\frac{1 - D + p[(R - R') - q(R - D)]}{1 - pq} \geq \frac{1 - D}{1 - pq},$$

because $R - R' \geq q(R - D)$ is equivalent to $F_1 \geq 0$. From this, we can conclude that, in the interval $]F_0, R - D]$, Design 2 delivers a higher value for lower F, which dominates Design 1. □

With Design 0 and Design 2, the payoff is either R or 0. Neither of the outcomes triggers the conversion of the CoCo bond into equity, and the banker either repays the face value of debt if the outcome is R, or defaults if it is 0. Consequently, CoCo bond and subordinate debt under Design 0 and Design 2 are equivalent securities and external investors would pay the same price for them, when they have the same face value. The optimality of CoCo contract vis-à-vis the price of the security follows Proposition 2, as stated in the following proposition.

Proposition 6. *Under Scenario 1 of Lemma 1, if $F_1 \geq 0$, the banker's value as a function of the amount raised by issuing CoCo bonds is*

$$\mathcal{E}^C(P) = \begin{cases} R - 1 & \text{if } P^F \in [1 - D, R - D - \frac{G}{pq}[\\ (1 - pq)R - 1 + pqD + G & \text{if } P^F \in [R - D - \frac{G}{pq}, (1 - pq)(R - D)] \end{cases}$$

A.2 Non-voting shares

The next lemma indicates that, if $F_1 > 0$, equity financing fail to prevent risk-shifting for any value of α. In fact, even if the banker is allowed to keep the entire residual amount with $\alpha = 1$, the ex-post risk-shifting still generates a higher payoff to the banker.

Lemma 19. *Under Scenario 1 of Lemma 1, and for $F_1 \geq 0$, Design 1 is infeasible.*

Proof. For Design 1 to be feasible, it should be $\Pi_1^S > \Pi_0^S$ and $\Pi_1^S > \Pi_2^S$. However, we have shown that the first is equivalent to $\alpha > \alpha_0$ and the second is never true for $F_1 \leq 0$. □

Lemma 20. *Under Scenario 1 of Lemma 1, and for $F_1 \geq 0$, Design 0 is attained for $\alpha < \alpha_1$ and $P_0^S = \alpha(R - D)$.*

Proof. The proof is the same as for Lemma 13, and then we observe that $(1 - q)R - R' + qD \geq 0$ is equivalent to $F_1 \geq 0$. Then Design 0 is feasible for $\alpha < \alpha_1$. □

Lemma 21. *Under Scenario 1 of Lemma 1, and for $F_1 \geq 0$, Design 2 is attained for $\alpha \in [\alpha_1, 1]$ and $P_2^S = \alpha(1 - pq)(R - D)$.*

Proof. The conditions for Design 2 are $\Pi_2^S \geq \Pi_0^S$ and $\Pi_2^S \geq \Pi_1^S$. As showed before, the first condition is equivalent to $\alpha \geq \alpha_1$. The second condition does not impose any restriction on α, because it is gives $R' - D - (1 - q)(R - D) \leq 0$, which is equivalent to $F_1 \geq 0$. □

Lemma 22. *With equity financing, under Scenario 1 of Lemma 1, and for $F_1 \geq 0$, the optimal values to the banker in each design is*

$$\mathcal{E}_S^0 = R - 1 \textit{ for } \alpha > \frac{1-D}{R-D} \textit{ and } \alpha \in [0, \alpha_1[,$$

$$\mathcal{E}_S^2 = (1-pq)R - 1 + pqD + G \textit{ for } \alpha > \frac{1-D}{(1-pq)(R-D)} \textit{ and } \alpha \in [\alpha_1, 1].$$

Proof. With reference to Lemma 6, the optimal value in Design 0 is $\mathcal{E}_0^S = R - 1$, which is achievable if $\frac{1-D}{R-D} < \alpha_1$, that is $R - 1 > \frac{G}{pq}$. This condition is always satisfied from Assumption 8. Design 2 generates a value of $(1-pq)R - 1 + pqD + G$ if $\frac{1-D}{(1-pq)(R-D)} < 1$, that is $(1-pq)R - 1 + pqD > 0$, which is always satisfied under Assumption 6. $\square$

We finally state the optimality of using non-voting share to finance the project as a function of the capital raised from outside.

Proposition 7. *Under Scenario 1 of Lemma 1, and for $F_1 \geq 0$,*

$$\mathcal{E}^S(P) = \begin{cases} R - 1 & \textit{if } P^S \in [1-D, R-D-\frac{G}{pq}[\\ (1-pq)R - 1 + pqD + G & \textit{if } P^S \in [R-D-\frac{G}{pq}, (1-pq)(R-D)] \end{cases}$$

Proof. Under the assumptions, the break-even price of equity issuance is

$$P^S = \begin{cases} \alpha(R-D), & \text{if } \alpha \in [\frac{1-D}{R-D}, \alpha_1[, \\ \alpha(1-pq)(R-D), & \text{if } \alpha \in [\max\{\frac{1-D}{(1-pq)(R-D)}, \alpha_1\}, 1]. \end{cases}$$

P^S is monotonically increasing in α, so it suffices to calculate the value at the boundaries of the relevant intervals. Where Design 0 is optimal, the capital raised by the bank by issuing equity is $P^S(\frac{1-D}{R-D}) = 1 - D$. The maximum amount with Design 0 is $P^S(\alpha_1) = R - D - \frac{G}{pq}$.

For Design 2, the maximum amount is $P^S(2) = (1-pq)(R-D)$. As for the minimum amount, if $\frac{1-D}{(1-pq)(R-D)} > \alpha_1$, the minimum security price is $P^S(\frac{1-D}{(1-pq)(R-D)}) = 1 - D$. Otherwise, if $\frac{1-D}{(1-pq)(R-D)} < \alpha_1$, it is $P^S(\alpha_1) = (1-pq)(R - D - \frac{G}{pq})$. The minimum amount raised by Design 2 is lower than the maximum amount raised by Design 0, because $1 - D < R - D - \frac{G}{pq}$, and $(1-pq)(R-D-\frac{G}{pq}) < R - D - \frac{G}{pq}$. As $\mathcal{E}_S^0 > \mathcal{E}_S^2$,

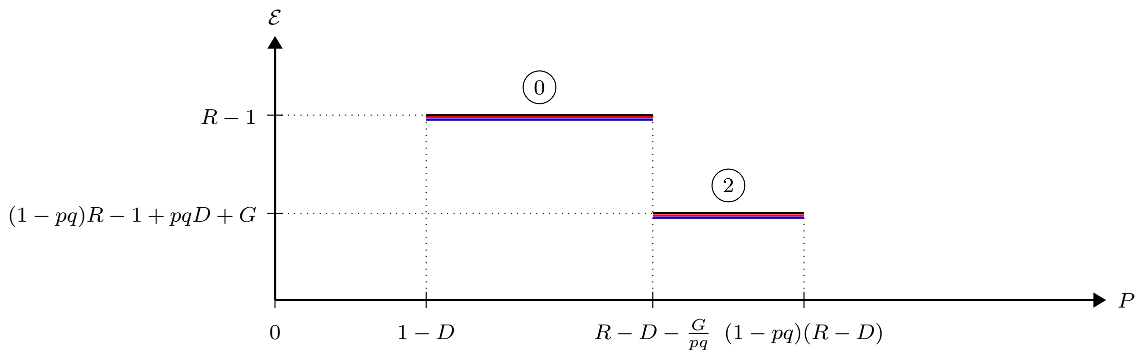


Figure 13: Optimal value to the banker against the amount raised by issuing the security: CoCo bonds (black) vs non-voting shares (red) vs subordinated debt(blue) for $F_1 \geq 0$.

the banker chooses Design 0 over Design 2 when both are feasible. Namely, Design 2 is optimal only if $P \in]R-D-\frac{G}{pq}, (1-pq)(R-D)]$. $\square$

A.3 Comparison

In Figure 13, we compare the optimal value for the banker of using CoCo bonds (black), non-voting shares (red) and subordinated debt (blue), as a function of the amount raised from external financiers, for $F_1 \geq 0$. Notably, three securities deliver the same value to the banker. For $P \in [1-D, R-D-\frac{G}{pq}[$, all three securities deliver a first best outcome. Similarly, with all three securities, the banker can only implement Design 2 if she needs to raise a higher capital from outside, and her value is $(1-pq)R-1+pqD+G$. The following proposition summarizes the result.

Proposition 8. *When $F_1 \geq 0$, none of those three security outperforms the others.*

The intuition for this result is that none of them successfully prevents risk-shifting when the outcome is R'. On the one hand, an undercapitalized bank chooses Design 2 and raises at most $(1-pq)(R-D)$. On the other, a well-capitalized bank avoid shirking by implementing Design 0, which limits the amount raised from outsiders. As we have shown, these decisions solely depend on the bank's financial condition and not on type of security. Therefore, the three securities are perfect substitutes for $F_1 \geq 0$, which justify our decision not to include this case in the main analysis.

B Case with $\frac{G}{pq} \leq p(R-R')$ and $F_1 < 0$.

In the baseline model, we focus on the case with $\frac{G}{pq} > p(R-R')$, where the upper bound of security price with the non-dilutive CoCo bond is greater than the upper bound for the price of the safe one. In this appendix, we analyze the case $\frac{G}{pq} \leq p(R-R')$.

The optimality of CoCo bonds changes due to the dominated Design 1. Compared to Proposition 1, the optimal equity value is now $\mathcal{E}^C(P) = R-1$ if $P \in [1-D, R-D-\frac{G}{pq}]$. For the financing needs higher than $R-D-\frac{G}{pq}$, the banker can no longer afford it because the maximum amount that Design 1 can raise is lower than $R-D-\frac{G}{pq}$ from $\frac{G}{pq} > p(R-R')$.

As for debt financing, Proposition 2 states Design 0 with subordinated debt is the only optimal design that delivers a positive value to the banker if $\frac{G}{pq} \leq pq(R-D)$. Given that $\frac{G}{pq} \leq p(R-R')$ and $p(R-R') < pq(R-D)$ from $F_1 < 0$, $\frac{G}{pq} \leq pq(R-D)$ is always satisfied. Hence, the banker receives $\mathcal{E}^D(P) = R-1$ by issuing safe debt for $P \in [1-D, R-D-\frac{G}{pq}]$.

Non-voting share is the only security that might still allow the banker to implement Design 1. That is because the condition of no optimal Design 1 is $\frac{R-D}{p(R-R')}G \leq p(R-R')$, while $\frac{R-D}{p(R-R')}G > \frac{G}{pq}$ from Proposition 4. There are three possible cases:

1. $\frac{G}{pq} < \frac{R-D}{p(R-R')}G \leq p(R-R') < R-1$;
2. $\frac{G}{pq} \leq p(R-R') < \frac{R-D}{p(R-R')}G < R-1$;
3. $\frac{G}{pq} \leq p(R-R') < R-1 < \frac{R-D}{p(R-R')}G$.

In Case 1, similar to CoCo bonds and subordinated debt, Design 1 is dominated by Design 0, and the optimal banker's value is $\mathcal{E}^S(P) = R-1$ if $P^S \in [1-D, R-D-\frac{R-D}{p(R-R')}G[$.

In Case 2, if $p(R-R') < \frac{R-D}{p(R-R')}G$, the maximum value raised from Design 1 with non-voting shares is greater than $R-D-\frac{R-D}{p(R-R')}G$. The ratio $\frac{R-D}{p(R-R')}$ represents the residual income after the deposit repayment in the R state over the value destroyed by the shirking action. The higher value of it suggests the shirking action is less costly to the bank. As a result, the bank is able to payout a higher value to the outsiders. The optimal equity value associated with this is

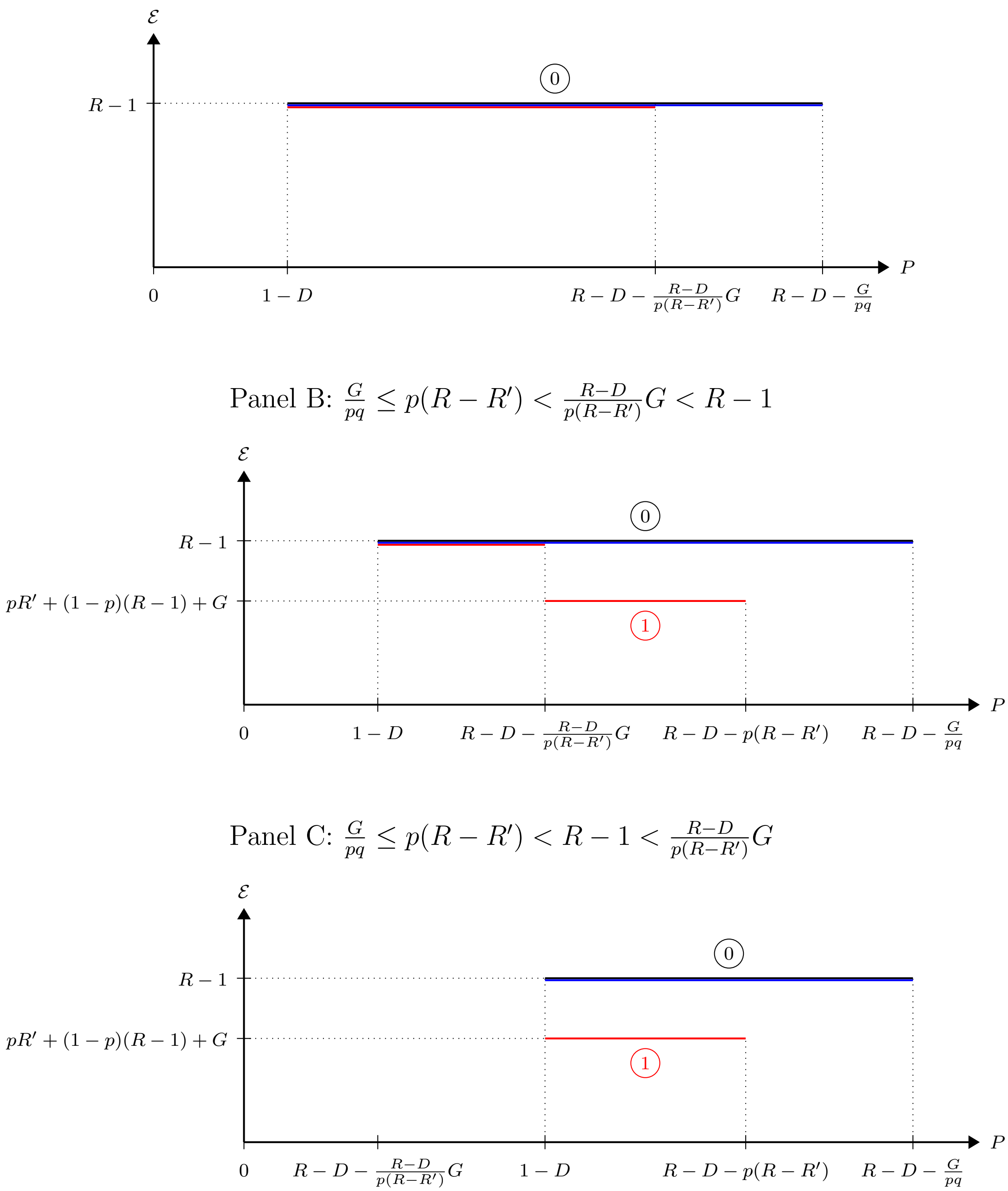
$$\mathcal{E}^S(P) = \begin{cases} R - 1 & \text{if } P^S \in [1 - D, R - D - \frac{R-D}{p(R-R')}G[\\ pR' + (1-p)R - 1 + G & \text{if } P^S \in [R - D - \frac{R-D}{p(R-R')}G, R - D - p(R - R')] \end{cases}$$

In Case 3, Design 0 is unaffordable and Design 1 is the only one delivering a positive value: $\mathcal{E}^S(P) = pR' + (1-p)R - 1 + G$ if $P^S \in [1 - D, R - D - p(R - R')]$.

It is worth noting that although Design 1 might be available for non-voting shares, the maximum amount raised from it $R - D - p(R - R')$ is lower than $R - D - \frac{G}{pq}$. That is due to $\frac{G}{pq} \leq p(R - R')$. That means Design 1 with non-voting shares is always dominated by Design 0 with CoCo bonds and subordinated debt. In Figure 14, Panel A, B and C represent the three cases considered above.

Overall, we can conclude CoCo bonds and subordinate debt would not create any risk-shifting incentives, but non-voting share allow to raise less funds and possibly deliver a lower value to the banker. Therefore, the banker would be indifferent to issuing safe CoCo bonds and subordinated debt, and non-voting share would be dominated by either of them.

Panel A: $\frac{G}{pq} < \frac{R-D}{p(R-R')}G \leq p(R-R') < R-1$



Panel B: $\frac{G}{pq} \leq p(R-R') < \frac{R-D}{p(R-R')}G < R-1$

Panel C: $\frac{G}{pq} \leq p(R-R') < R-1 < \frac{R-D}{p(R-R')}G$

Figure 14: Optimal value to the banker against the amount raised by issuing the security: CoCo bonds (black) vs non-voting shares (red) vs subordinated debt (blue) for $\frac{G}{pq} \leq p(R-R')$ and $F_1 < 0$.

C Additional tables

Table 6 contains the sample of banks used in the empirical analysis. These banks are or have been G-SIBs, in the period from 2011 to 2020, as identified by the FSB, in consultation with the Basel Committee on Banking Supervision (BCBS) and national authorities.

Table 6: Banks included in the empirical sample

AGRICULTURAL BANK OF CHINA LIMITED	BANCO BILBAO VIZCAYA ARGENTARIA SA
BANCO SANTANDER SA	BANK OF AMERICA CORPORATION
BANK OF CHINA LIMITED	BANK OF NEW YORK MELLON (THE)
BARCLAYS PLC	BNP PARIBAS
BPCE GROUP	CHINA CONSTRUCTION BANK CO., LTD
CITIGROUP INC	CREDIT AGRICOLE
CREDIT SUISSE GROUP AG	DEUTSCHE BANK AG
GOLDMAN SACHS GROUP, INC	HSBC HOLDINGS PLC
INDUSTRIAL & COMMERCIAL BANK OF CHINA	ING BANK NV
JPMORGAN CHASE & CO	MITSUBISHI UFJ FINANCIAL GROUP, INC.
MIZUHO FINANCIAL GROUP	MORGAN STANLEY
NATWEST GROUP PLC	NORDEA BANK ABP
ROYAL BANK OF CANADA	SOCIETE GENERALE
STANDARD CHARTERED PLC	STATE STREET CORPORATION
SUMITOMO MITSUI FINANCIAL GROUP, INC	TORONTO DOMINION BANK
UBS AG	UNICREDIT SPA
WELLS FARGO & COMPANY	