Non-dilutive CoCo Bonds: A Necessary Evil?

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Abstract

We empirically document and theoretically investigate why non-dilutive CoCos are prevalent, even though advocates of CoCos suggest such securities should be dilutive to reduce bank risk-taking. In an agency model with two subsequent moral hazards, we show that while dilutive CoCos deter ex-ante risk-taking and prevent a bank from being undercapitalized, penalizing existing shareholders with dilution when the bank is already undercapitalized leads to risk shifting. CoCos' designs and risk implications depend on banks' equity capitalization, with non-dilutive CoCos particularly attractive to capital-constrained banks, because such securities can maximize the banks' financing capacity by tackling only the ex-post risk shifting.

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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 inclusion of contingent convertible bonds (CoCos) to 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. Researchers and regulatory authorities promote CoCos not only to overcome banks' reluctance to re-capitalize themselves using common equity in a crisis but also for their potential to punish bank shareholders' risk-taking by diluting their claims upon CoCos' conversion. 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.

[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.

While 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 the extent to which shareholders are penalized 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. Such securities, arguably, appear to 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 3).

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 — until the COVID crisis and its instantaneous (albeit relatively short-lived) aggregate negative impact on the stock market. As illustrated in Table 1, upon the shock, the market prices of banks' common equity dropped below the pre-set conversion prices for most of the banks,[4] while the banks' CET1 ratios remained far above the trigger level. Had a banking crisis happened with banks' CET1 ratios falling below the conversion trigger, it is likely that the market price of banks' common stock would be even lower. CoCo investors, who have to convert their bonds for equity at a price lower than the pre-set conversion price, would lose out relative to the face value of their

[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.

[4] Among all G-SIBs that issued CoCos, HSBC stock price was the only one that did not fall below the CoCo conversion trigger at the start of the COVID crisis. However, even in this case, the lowest price (about £2.83 per share) was very close to the conversion price (£2.70 per share). In an actual banking crisis, when the bank's CET1 ratio drops dramatically also the stock price is likely to fall below the conversion price. Therefore, in our opinion, the evidence suggests all AT1 CoCo issued by G-SIBs are non-dilutive.

bond; equity holders, instead of being diluted, would be better off relative to the CoCo bond repayment.

Table 1: Equity-conversion CoCos: pre-set conversion price vs. market prices upon the COVID shock

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

In sum, it appears that neither PWD CoCos nor equity conversion CoCos in the prevailing market practice would impose severe penalty for equity holders when the write-down or conversion is triggered. This strongly contrasts the envisioning that CoCos can deter share holders' risk-taking by diluting their shares upon conversion.

While CoCos may have fallen short of the original envisioning for not being dilutive 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 ones) 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 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 these empirical observations, we explain why dilutive CoCos are rarely, if ever, observed in practice and the implications of non-dilutive designs for banks' risk-taking incentives. Our theory 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. Such a state of low equity capitalization is where the shareholders' incentives for risk shifting are the strongest, so it is essential for CoCos to mute such perverse incentives. Indeed, if a bank's CoCos are highly dilutive, there will be little left for existing shareholders upon the CoCos' conversion, which increases the risk shifting incentive. While the bank can be more resilient with 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 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.

For the design of CoCos, a trade-off can emerge between perfectly containing the agency problems and maintaining the financing capacity of the security: when a CoCo is designed to both induce screening and avoid risk shifting, it will create more bank value but also leaves much rent to the banker and limits the financing capacity of the security. In contrast, non-dilutive CoCos can generate higher pledgeability for the bank since the design only tackles one moral hazard problem — risk shifting — does not concede much rent to the banker. Our theory shows that CoCos' designs and their impacts on bank risk-taking can depend on the capital position of the bank. While a well-capitalized bank can use either dilutive or non-dilutive CoCos without triggering any risk-taking, a capital-constrained bank may have to use non-dilutive CoCos to boost its financing capacity at the cost of allowing for a degree of risk-taking. In this sense, the non-dilutive features is a 'necessary evil' that a constrained bank has to accept, a compromise in design that sacrifices ideal risk management for financing capacity.

We highlight that non-dilutive CoCos are rather unique securities, because 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. When that is the only goal of the CoCo design, this feature also allows for greater pledgeability and facilitate financing.

While we do not present 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] Compared to them, CoCos can contain bank risk taking for a wider range of parameters and in fact dominate them particularly for capital-constrained banks. More precisely, compared to subordinated debt, CoCos can avoid ex-post risk shifting when a bank has higher financing needs. Relative to non-voting shares, CoCo increase the ex-ante funding opportunities 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 state.

We make three important contributions. First, we show that the relationship between the dilutive conversion of CoCos and their implications for bank risk-taking incentives can be subtler than the literature seems to suggest: CoCos do not necessarily need to be dilutive to discourage risk-taking — non-dilutive CoCos issued by well-capitalized banks can also deter risk-taking. Requiring a less capitalized bank to issue dilutive CoCos, on the other hand, can result in high risks. Second, we rationalize 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. Our theory emphasize non-dilutive CoCos' effectiveness in mitigating risk shifting and their role in

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

boosting banks' financing capacity. Third, our paper sheds light on how designs of CoCos are related/determined by banks' balance sheet characteristics, which provides testable empirical hypotheses for future studies. We predict that non-dilutive CoCos are more likely to be issued by banks that are less-than-ideally capitalized. Overall, We suggest that CoCos' designs and their implications for banks' risk-taking behaviors can only be understood and assessed in the context of banks' broader capital structure.

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. We believe that, despite the generous regulatory treatment of AT1 designation, CoCos are no substitutes for banks' equity capital. Instead, the effectiveness of CoCos in containing risk-taking relies on banks' equity capitalization, and one possible interpretation of the prevalence of non-dilutive CoCos is that there are still room for further capitalization in the banking sector. On the other hand, we believe that it is justifiable for CoCos to be considered as regulatory capital since our model reveals that CoCos can dominate subordinated debt and non-voting shares that are also present in the regulatory capital stack.

Related Literature: Many researchers, e.g., Flannery (2016, 2014) and Calomiris and Herring (2013), advocate CoCos as securities that can automatically replenish bank capital and can correct distorted bank risk-taking incentives with its equity dilution feature. Pennacchi and Tchistyi (2019) formally show that, with a market trigger, dilutive

CoCos can penalize bank shareholders for risk-taking and promote financial stability.[6] Hilscher and Raviv (2014) argue that with a properly designed dilution feature, CoCos can eliminate banks' risk shifting incentive, even during periods of financial distress. Himmelberg and Tsyplakov (2020) warn that when a bank's financial health is near the trigger threshold, PWD CoCos can create incentives for bank shareholders to destroy the bank's value in an attempt to trigger write-down and get a transfer from CoCo investors. 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 a more optimistic assumption than market reality.[7]

Researchers like Admati (2014) 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. Pennacchi (2010), Berg and Kaserer (2015) and Chan and van Wijnbergen (2017), 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 appear to 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 theoretical conjectures that depending on a bank's capitalization, strong dilution may not be necessary for CoCos to correct

[6]While both Pennacchi and Tchistyi (2019) and Sundaresan and Wang (2015) 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 Zeng (2014) and Yu (2016), 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.

risk-taking incentives, and that even if non-dilutive CoCos are used as a way to stretch a capital-constrained bank's balance sheet, their non-dilutive feature can still contain the incentives for gambling-for-resurrection of a bank that is already undercapitalized in the conversion state.

Other than the non-dilutiveness of CoCos, the literature also raised other concerns regarding the hybrid securities. In a global-games framework, Chan and van Wijnbergen (2014) 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. Fiordelisi et al. (2020) 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 on whether CoCos are in fact going-concern securities. De Spiegeleer and Schoutens (2013) 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 Martynova and Perotti (2018). The authors provide a theory to explain the prevalence of PWD CoCos, but their setting is such that PWD CoCos with full and permanent write-down features are optimal independent of a bank's overall capital structure. We instead emphasize that while both dilutive and non-dilutive CoCos can achieve first-best risk level of the bank, using non-dilutive CoCos to achieve that requires the bank to be sufficiently equity capitalized. Otherwise, non-dilutive CoCos emerge as a 'necessary evil' for a capital-constrained bank to boost its financing capacity at the cost of reducing bank value. In this sense, non-dilutive CoCos only enable the bank to achieve a second-best in our model.[8]

On the empirical side, Avdjiev et al. (2020) 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. Fiordelisi et al. (2020) 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 (despite predominantly PWD CoCos) have indeed shown more prudence in their loan pricing. Our theoretical prediction that non-dilutive CoCos can reduce risk-taking by undercapitalized banks also finds its empirical support in Vallée (2019). The author shows via the Liability Management Exercises during the 2007-2008 financial crisis, European banks booked capital gains at the cost of subordinated debt holders, leading to lower perceived risks from the market.

In what follows, Section 2 sets out our basic model. We study in Section 3 different CoCo designs — in terms of their feasibility, their financing capacity, and the impact on existing shareholder values. Section 4 compares CoCos with two other common securities that are considered as regulatory capital, i.e., subordinated debt and non-voting shares, and shows that Section 5 provides an empirical evaluation on whether CoCos have reduced bank risk-taking with syndicated loan market data. Section 6 concludes.

[8] Furthermore, since full and permanent write-downs severely hurt CoCo investors, a CoCo with such features do not maximize the security's financing capacity in our model. As a result, a bank that seeks to maximize its financing capacity would opt for CoCos with weaker non-dilutive features, which appears to be consistent with the existence of CoCos with only partial and temporary write-down features (e.g., a pause in coupon payments) in reality.

2 The model

The economy has three dates, $t = 0, 1, 2$, and comprises a bank, and two groups of active economic agents: a banker who is the owner/manager of the bank, and the bank's outside investors. The bank also has access to a pool of inactive retail depositors. All agents are risk-neutral and the risk-free rate is normalized to zero.

The baseline capital structure of the bank comprises the retail deposits, D, and equity funding provided by the banker. The equity claim is protected by limited liability. We also assume that the retail deposits are fully insured, and that deposit insurance premium has been already paid so that the retail depositors' claims are risk free.[9]

The banker maximizes her expected payoff at $t = 0$ by investing in a loan portfolio, which requires 1 unit of initial capital input and matures at $t = 2$. We assume that $D < 1$, to avoid the trivial case where no additional external financing is needed. To finance the project, the banker issues securities to outside investors, who will bid competitively and only break even from purchasing the securities. We will mainly consider how CoCo bonds can be designed to meet the financing need, but will also consider two alternative forms of bank regulatory capital, subordinated debt and non-voting shares. The banker has an endowment $E \geq 0$ invested in perfectly competitive and arbitrage-free capital markets. Because such an investment is a zero-NPV activity, the banker will invest in the loan portfolio via equity only if this is a positive-NPV decision and if E is higher than the financing gap between the unit investment need and the amount raised from depositors and outside investors.

[9] As it will be clear later, the deposit insurance will never be used in the equilibrium as depositors will always be fully repaid by the bank. This baseline amount of retail debt is introduced to (1) allow us to define bankruptcy and CoCos as going-concern securities, and (2) to generate potential risk-shifting incentives.

We model two moral hazard problems on the banker's side. First, having decided to invest in the loan portfolio, the banker has a choice to screen the loans or not. For simplicity, we assume that the screening will make the loan portfolio risk-free and generate 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 $R' < R$ with probability p, while with probability $(1-p)$ the return remains R. We assume that while shirking only leads to mild loan delinquency and will not lead to default on the retail deposits, screening is socially efficient and the expected loss on loans from no screening exceeds the banker's private benefit. Also, to allow for a risky bank to be financed on the equilibrium path, we assume that the expected cash flow of the loan portfolio is positive even in the absence of the banker's screening. These assumptions are summarized by the following parametric conditions respectively:

$$R' > D \tag{1}$$

$$p(R - R') > G \tag{2}$$

$$(1-p)R + pR' > 1 \tag{3}$$

Second, the banker privately learns the terminal return of the long-term investment on the intermediate date $t = 1$ and can 'gamble for resurrection' when she expects the return to be R'. In particular, we assume that the banker can take a negative-NPV 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.[10] The upside of risk shifting restores the cash flow to R and conceals the fact that the banker has not screened the

[10]For example, the banker may take position in derivatives for speculative purposes, or evergreen a borrower whose credit quality has already deteriorated, betting on their financial resurrection.

loans properly. The loss on the downside, however, will make the bank default on its retail debt, in which case, the deposit insurance scheme has to pay D to the depositors. While the outside investors can observe the terminal cash flow of the bank, they cannot observe the banker's action at $t = 1$. In effect, taking this project is tantamount to shifting the risk to the deposit insurance fund.

We assume that the terminal returns are verifiable at $t = 2$ so that the banker will never take the risk-shifting action when she learns the terminal-date return of the investment to be R. This is because the outcome of risk-taking, either $2R - R'$ or $R - R'$, will perfectly reveal the banker's risk-taking, and a regulator can detect the risk-taking and deters it by imposing taxes or other penalties. On the other hand, risk-taking when the banker learns the loan portfolio's terminal return to be R' cannot be ex post detected or easily deterred, since the return R resulting from successful risk-taking cannot be differentiated from the safe return generated from screening.

We assume that although the follow-on project destroys value, the total cash flow to the bank, including the expected transfer from the deposit insurance, pqD, is still positive — even if the banker shirks and takes the follow-on project. The assumption ensures a bank with a positive probability of default may be financed in the first place, and therefore there is a need to design securities to prevent such risk-taking. These assumptions are summarized by the following parametric conditions:

$$(1-q)R - R' < 0 \tag{4}$$

$$(1-pq)R - 1 + pqD > 0 \tag{5}$$

The sequential nature of the two value-destroying moral hazard actions are summarized by the timeline in Figure 1.

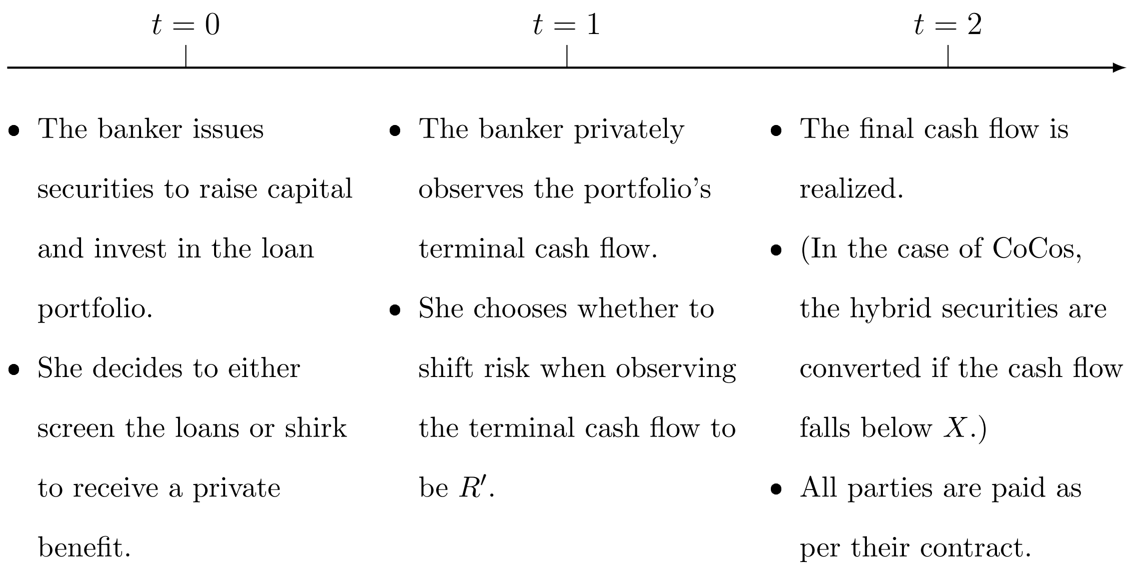


Figure 1: Timeline of the model

The bank's value depends on the moral hazard actions, if any, that the banker takes. Specifically, the banker can choose one of the following three risk levels. We will use subscript $i \in \{0, 1, 2\}$ to indicate the risk level of the bank, with the index i reflecting the number of moral hazard actions taken by the banker. Since the external financiers are assumed to only break even, the banker will obtain the full NPV from investing in the loan portfolio — provided that the investment can be financed in the first place. We denote by $\mathcal{E}_i$ the NPV of a bank with risk level i.

Level 0: The banker screens the loans and does not shift risks, and the bank's NPV is

$$\mathcal{E}_0 = R - 1.$$

Level 1: The banker shirks from screening but does not shift risks, which leads to an NPV of

$$\mathcal{E}_1 = pR' + (1 - p)R - 1 + G.$$

Level 2: The banker both shirks and shifts risk, which leads to an NPV of

$$\mathcal{E}_2 = (1 - pq)R - 1 + pqD + G.$$

Moving from Level 0 to 1, the banker destroys value due to the lack of screening but gains the private benefit from shirking. Moving from Level 1 to 2, the banker destroys additional value with inefficient risk-taking but gains pqD from shifting the risk to the deposit insurance fund. Level 0 is the first-best allocation, and Level 1 is a second-best, a compromise that allows for shirking but still excludes risk-shifting. $\mathcal{E}_0 > \mathcal{E}_1$ always holds under our assumption of efficient screening. We assume that the parameters are such that $\mathcal{E}_2 < \mathcal{E}_1$, so that it is not always in the interest of the banker to engage in risk-shifting. This assumption is equivalent to the following inequality

$$R - D < \frac{R' - D}{1 - q}. \tag{6}$$

For the banker's investment problem, we analyze three alternative classes of securities: CoCo bonds (C), subordinated debt (B), and non-voting shares (S). Each class $j \in \{C, B, S\}$ has (a vector of) design parameters, θ^j, with respect to which the banker maximizes her value. For a bank of risk level $i \in \{0, 1, 2\}$, the fair price of a security j is denoted by $P_i(\theta^j)$, and to finance a bank of risk level i, the banker needs to put in $K_i(\theta^j) = 1 - D - P_i(\theta^j)$, together with the proceed from selling the security, $P_i(\theta^j)$, and retail deposit, D. Such a bank will be financed only if the banker's endowment E exceeds the required equity input $K_i(\theta^j)$, in which case the bank generates an expected payoff for equity $\Pi_i(\theta^j)$ and gives the banker an incremental value of $\Pi_i(\theta^j) - K_i(\theta^j)$. The risk level of the bank affects the value of the security, the required capital input from the banker, as well as the banker's expected payoff. Therefore, the banker's program with a class-j security is[11]

$$\max_{(i,\theta^j)} \; \Pi_i(\theta^j) - K_i(\theta^j)$$

$$\text{s.t.} \quad E \geq K_i(\theta^j) \qquad \text{(budget constraints)}$$

$$\Pi_i(\theta^j) - K_i(\theta^j) \geq \Pi_{-i}(\theta^j) - K_{-i}(\theta^j) \qquad \text{(incentive constraints)}$$

Because external financiers are assumed to only break even, the banker's NPV depends only of the risk level, and not of the issued security. Formally, $\mathcal{E}_i = \Pi_i(\theta^j) - K_i(\theta^j)$ holds for any $j \in \{C, B, S\}$.[12] Because $\mathcal{E}_0 > \mathcal{E}_1 > \mathcal{E}_2$, the banker's maximization program with a security j is equivalent to designing the security to generate a sufficiently high financing capacity so that banker's endowment E can finance a bank of the lowest possible risk level.[13]

In what follows, we analyze the solution of the banker's program with CoCo bonds (Section 3), and then compare it to the solutions with subordinated debt (Section 4.1) and non-voting shares (Section 4.2).

[11]The program allows for $K^j < 0$, in which case the banker will receive an upfront payout.

[12]The simple proof of this statement is in Appendix A.1.

[13]This is because the competition in the capital market enables the agent (the banker in our setting) to obtain the full NPV of the investment. So the agent will try to achieve the most socially efficient allocation subject to feasibility constraints, a feature that is generic to models with settings like Holmstrom and Tirole (1997).

3 CoCo bonds

To model CoCos as going-concern securities, we assume that a CoCo bond has a conversion trigger $X > R' > D$.[14] The CoCo stays as a bond and pays a face value of F when the bank's cash flow exceeds X. When the bank's cash flow falls below X, the CoCo will be converted to a $\lambda \in [0, 1]$ fraction of equity while the banker, as the existing shareholder, receives a fraction $1 - \lambda$ of total outstanding shares after the conversion. Figure 2 shows the ordering of the terminal payoffs and the CoCo conversion interval.

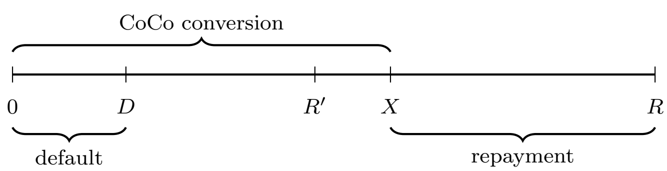


Figure 2: Conversion and repayment of CoCo bond.

Given the conversion trigger, a CoCo bond is fully characterized by two parameters, F and λ. Hence, in what follows $\theta^C = (F, \lambda)$ which is chosen in the set $\mathcal{C} = [0, R-D] \times [0, 1]$, with the upper bound $R - D$ for F being a consequence of limited liability of equity investment. Note that there are only two states where a CoCo bond can generate any positive payoff: R' (the conversion state) and R (the non-conversion state).[15] While λ pins down the CoCo's payoff in the R'-state, F pins down the CoCo's payoff in the R-state.

A CoCo bond is dilutive if the investors of the CoCo bond receive more than the face value of the bond upon CoCo conversion, i.e., $\lambda(R' - D) \geq F$. Otherwise, the CoCo

[14] Given the bank's terminal cash flow can only be R, R', or 0, the alternative assumption that $X \in]D, R'[$ would lead to a trivial case where CoCos are only converted when the bank generates a zero payoff and CoCo investors receive nothing in conversion.

[15] Obviously, in the state where the cash flow is 0, CoCo investors will have to receive a zero payoff since the other claim holders are all protected by limited liabilities.

bond is non-dilutive.[16] This definition captures the fact that, as the bank's cash flow decreases from R to R' and triggers conversion, an increase in the CoCo investors' payoff must imply the banker/shareholder receives less, and her claim is diluted. Non-dilutive CoCos are unique securities as they are junior to equity. Indeed, CoCo holders lose value upon conversion (as compared to the principal of bonds they surrender), whereas equity holders are better off relative to the situation where they need to make CoCo bond repayments.

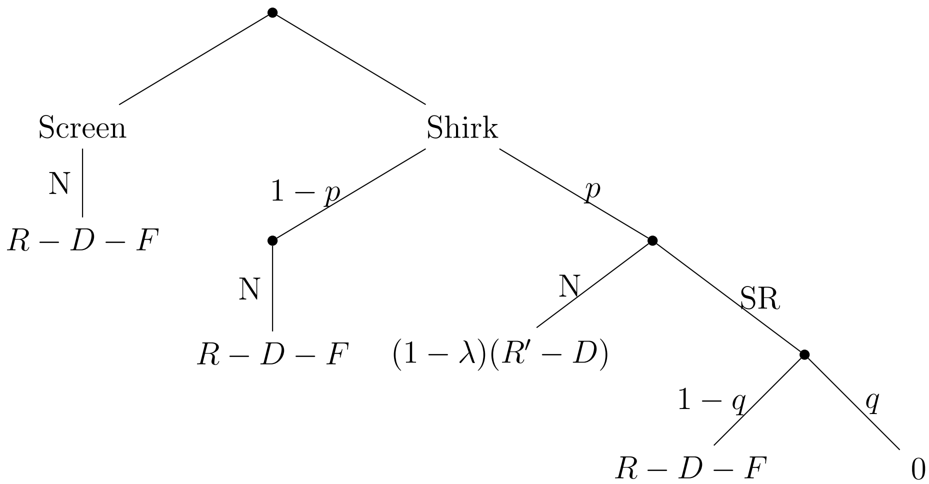
For a given CoCo design (F, λ), Figure 3 summarizes the banker's decisions and the ensuing cash flow to equity. Table 2 supplements the figure by showing the payoffs to all the parties in the different cash flow scenarios. Both illustrations omit the banker's private benefit G.

Table 2: Payoffs to all investors (excluding the banker's 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	$-D$

The equilibrium design of the CoCo bond depends on (i) the moral hazard actions (if any) that it entails and the corresponding payoff to the banker as the existing shareholder, and (ii) whether the CoCo bond can raise enough to finance the loan portfolio. We analyze these two aspects in Section 3.1 and Section 3.2, respectively.

[16]This notion is widely adopted in the literature. For examples, see Calomiris and Herring (2013) and Himmelberg and Tsyplakov (2020). Calomiris and Herring (2013) defines dilutive CoCo as those whose "conversion will leave the holders of CoCos with at least as much value in new equity as the principal of the bonds they surrender."



The banker decides either to screen the loan portfolio, making it generate a risk-free return R, or to shirk, making the return risky. In the latter case, the return is R' with probability p, and R otherwise. Next, the banker either leaves the initial investment unchanged (N), or shifts risk (SR), in which case the incremental cash flow is $-R'$ with probability q or $R-R'$ otherwise.

Figure 3: Cash flow to equity at $t=2$ (with the exclusion of private benefit).

3.1 CoCo designs and bank asset risks

For a given design of the CoCo bond, (F,λ), the banker's expected payoff depends on her strategy. It will be

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

when she screens at $t=0$, and therefore is not to shift risk at $t=1$. If she, instead, is to shirk at $t=0$ but not to take any chances at $t=1$ — even if the outcome is R' — the expected payoff is

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

Finally, if the banker both shirks and shifts risk, the expected payoff is

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

A CoCo contract can be designed to implement a certain strategy of the banker to achieve the corresponding risk level of the bank. For such a contract, we will call Design i the subset of $\mathcal{C}$ that induces risk level i. The design of CoCos is intricate because the banker can generate cash flow R with two possibilities that cannot be told apart by the outsiders: the banker can generate R by screening the loan portfolio to make it risk free, but she will generate the same cash flow if she shirks on screening and is lucky when taking her chances. As a result, assigning the banker a high payoff in state R generates incentives for screening but also motives for risk shifting. Similarly, while leaving the banker a high payoff in state R' mitigates her risk-taking, such a design also reduces the incentive to screen loans.[17]

Design 0

We first consider CoCo designs that induce no moral hazard action from the banker at all. Such designs ensure that the banker's payoff from screening and no subsequent risk shifting is greater than that from any moral hazard action at $t=0$ or $t=1$. That is, two incentive compatibility constraints, $\Pi_0^C \geq \Pi_1^C$ and $\Pi_0^C \geq \Pi_2^C$, must be satisfied. The first is equivalent to

$$\lambda \geq \frac{F-(R-R')+G/p}{R'-D} \equiv \lambda_0(F), \tag{7}$$

[17] The conflict between inducing effort and at the same time avoiding risk taking was first analyzed in Biais and Casamatta (1999). The authors derive an optimal leverage based on a mixture of equity and debt. By contrast, we analyze how a hybrid security, CoCo, should be designed to tackle the frictions.

and sets a lower bound on equity claimed by CoCo investors in the event of conversion. In other words, the CoCo investors need to receive a sufficiently large amount upon conversion. Because a CoCo contract is feasible only for $\lambda \in [0, 1]$, such an incentive constraint can hold only if $\lambda_0(F) \leq 1$ or

$$F \leq (R - D) - \frac{G}{p}. \tag{8}$$

The second, $\Pi_0^C \geq \Pi_2^C$, is equivalent to

$$F \leq (R - D) - \frac{G}{pq} \equiv F_0 \tag{9}$$

and sets an upper bound on the face value of the CoCo bond. For such a design to be feasible, F_0 must be positive. That is,

$$\frac{G}{pq} \leq R - D, \tag{10}$$

which is implied by inequality (2) and (6). Since both conditions (8) and (9) set upper bounds on F and the latter is more restrictive than the former for $q < 1$, we have the following lemma.

Lemma 1. *A CoCo bond* (F, λ) *with* $F \leq F_0$ *and* $\lambda \geq \max\{\lambda_0(F), 0\}$ *induces no moral hazard action from the banker. As the bank is risk free, the price of the CoCo bond is* $P_0^C(F, \lambda) = F$.

Intuitively, the banker will screen the loan portfolio if the reward for doing so is sufficiently high (i.e., a high payoff in the R-state) and/or the penalty for not doing so is sufficiently large (i.e., a low payoff in the R'-state). The former can be achieved with a low face value of the CoCo bond, as reflected by condition $F < F_0$. The latter can

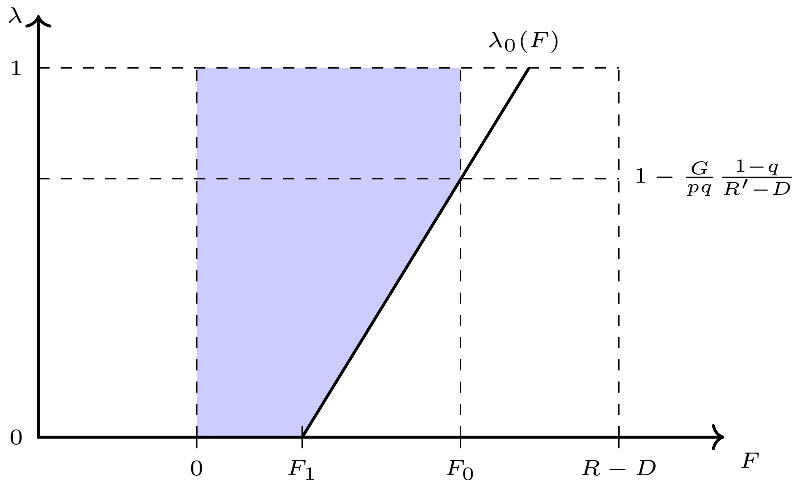


Figure 4: Feasibility of Design 0 of CoCo bond.

be achieved with a large payoff to the CoCo investors, that is $\lambda \geq \max\{\lambda_0(F), 0\}$. If these conditions are satisfied and the banker screens the loan portfolio, risk shifting will be avoided as the R'-state will not occur on the equilibrium path. Figure 4 depicts the subset of $\mathcal{C}$ where Design 0 is feasible.

Design 1

We now consider CoCo designs that concede the banker the private benefit of shirking but still prevent risk shifting at $t = 1$ if the terminal payoff is R'.

The banker does not screen the loan portfolio if $\Pi_1^C > \Pi_0^C$, which is equivalent to $\lambda < \lambda_0(F)$. This is feasible only if $\lambda_0(F) > 0$ and in turn requires

$$F > (R - R') - \frac{G}{p} \equiv F_1. \tag{11}$$

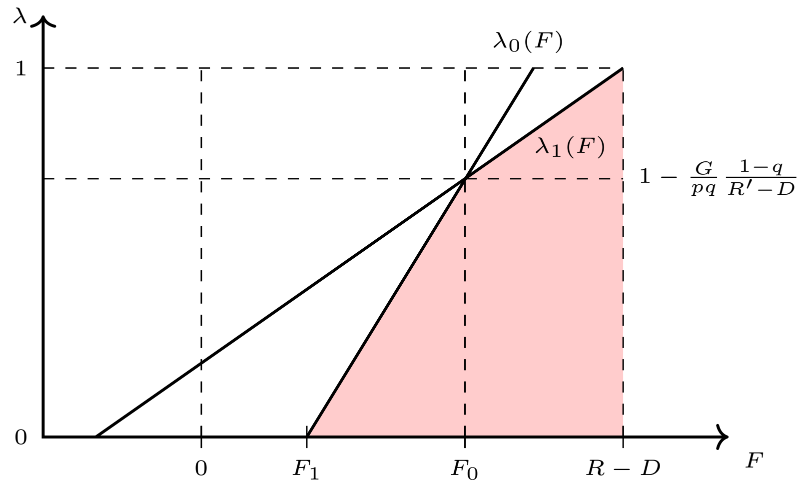


Figure 5: Feasibility of Design 1 of CoCo bond.

On the other hand, the banker will not shift risk if $\Pi_1^C \geq \Pi_2^C$, which implies

$$\lambda \leq \frac{(1-q)F - (R-R') + q(R-D)}{R'-D} \equiv \lambda_1(F) \tag{12}$$

and sets an upper bound on λ. The condition (6) guarantees $\lambda_1(F) > 0$ so that a choice of $\lambda < \lambda_1(F)$ is feasible.

Altogether, a CoCo bond design (F, λ) allows for shirking while avoiding risk shifting if $\lambda \leq \min\{\lambda_0(F), \lambda_1(F)\}$ and if $F \geq F_1$. We summarize the result in the following lemma and illustrate the relevant subset of $\mathcal{C}$ in Figure 5.

Lemma 2. *A CoCo bond (F, λ) induces no screening but prevents risk shifting if $F \geq F_1$ and $\lambda \leq \min\{\lambda_0(F), \lambda_1(F)\}$. The price of such a CoCo bond is $P_1^C(F, \lambda) = (1-p)F + p(R'-D)\lambda$.*

The intuition is that too large a fraction of equity allocated to CoCo investors would give the banker a strong incentive to shift risk. To prevent that, the amount allocated to CoCo investors should be limited, that is λ should have an upper bound. While a high face value F dampens the banker's incentive to screen the loans, which is allowed under this case, such a design also reduces the banker's upside from (and the incentive for) shifting risks.

Design 2

The banker will have incentives to both shirk and shift risk if the incentive constraints $\Pi_2^C \geq \Pi_0^C$ and $\Pi_2^C \geq \Pi_1^C$ are simultaneously met. As analyzed before, the first condition is equivalent to $F \geq F_0$, and the second condition to $\lambda \geq \lambda_1(F)$. Such designs are always feasible, as $F_0 < R - D$ and $\lambda_1(F) \leq 1$. Because this designs allows for shirking and risk shifting, the CoCo bond pays out only with probability $1 - pq$ and has a price $(1 - pq)F$. We summarize the results in the following lemma and depict the relevant subset of $\mathcal{C}$ in Figure 6.

Lemma 3. *A CoCo bond with a design $F \geq F_0$ and $\lambda \geq \lambda_1(F)$ would lead to both shirking and risk shifting. For such a design, the price of the CoCo bond is $P_2^C(F, \lambda) = (1 - pq)F$.*

3.2 CoCos' financing capacity and the equilibrium design

We now turn to the equilibrium design of the CoCo bond and show that the choice depends on CoCo's financing capacity and therefore the bank's equity capitalization.

As noted in Section 2, the banker will finance the least risky bank that she can afford, because a bank of a lower risk level generates a higher NPV which goes to the banker as the external financiers only break even. Therefore, from the banker's perspective, a CoCo contract has two features that matter: the risk level that it entails (or, the

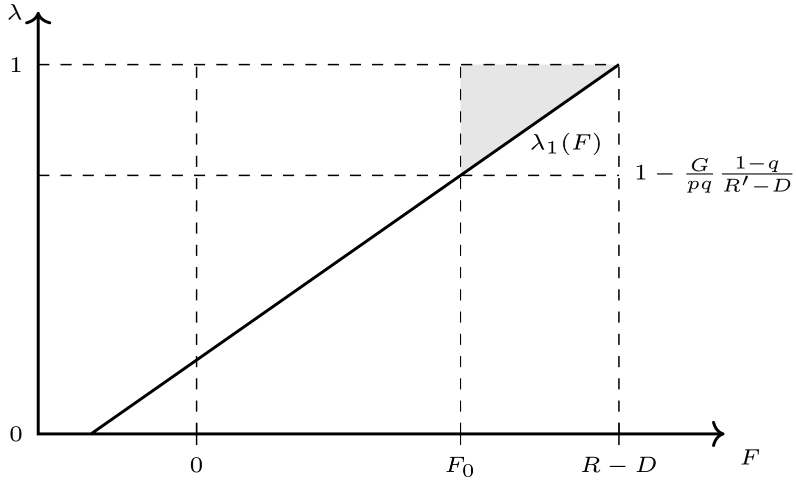


Figure 6: Feasibility of Design 2 of CoCo bond.

number of moral hazard actions that it will induce the banker to take), and the amount of financing that it allows the banker to raise.

We have established in Lemma 1 to 3 that each CoCo design (F, λ) can implement a particular risk level i and also carries a corresponding price $P_i^C(F, \lambda)$. Since the price of a CoCo bond varies with its two design parameters and a risk level can be implemented by a continuum of CoCo contracts, CoCos that entail the same risk level can carry different prices. Because the banker only cares whether a certain risk level can be financed with E, it is sufficient to focus on the maximum price that each design can be sold for. Such a maximum price is the financing capacity of CoCos that implement a particular risk level. It can be viewed as the pledgeable income of such CoCos, which is the highest income that can be distributed to the external financiers via CoCos without changing the banker's actions.

Comparing the financing capacity across three CoCo designs, we have the following proposition that shows CoCos of Design 1 can have the highest financing capacity. The proof is in Appendix A.2.

Proposition 1. *CoCos of Design* 0 *allow the banker to raise at most* $R - D - G/pq$*; and CoCos of Design* 1 *allows the banker to raise at most* $R - D - p(R - R')$*. The latter provides a greater financing capacity if and only if*

$$\frac{G}{pq} > p(R - R'). \tag{13}$$

CoCos of Design 1 always provides a greater financing capacity than those of Design 2.

Intuitively, while Design 1 reduces the total amount of cash flow that can be distributed among different claim holders, it allows for shirking and entails a lower rent that has to be kept for the banker and makes the amount available to CoCo investors. As a result, the pledgeable income to external financiers can increase when we move from CoCo Design 0 to Design 1. This is the case when the moral hazard problems are severe enough, i.e., inequality (13) holds. We will focus on this case for the rest of the paper.[18]

Assumption 1. *In the remaining of the paper, we will focus on a case where the moral hazard problems for the banker are sufficiently strong, i.e.,* $G/pq > p(R - R')$*.*

On the other hand, CoCos of a Design 1 always have a greater financing capacity than that of CoCos of Design 2. Intuitively, there is no conflict of interests between the banker and CoCo investors in the decision of shifting risks to the deposit insurance fund, so that the CoCo investors do not need to pay any agency rent to the banker for the banker to avoid risk shifting. Therefore, compared to Design 1, CoCos of Design 2 provide no greater financing capacity to the banker, because they only reduce the total amount of cash flow available. Formally, the price of a CoCo of Design 2 is $(1 - pq)F$

[18] For the opposite case, Design 1 will be dominated by Design 0 — both in terms of the value of bank and the security's financing capacity — and will never be issued by the bank. However, this would be inconsistent with empirical observations that CoCos are risky securities.

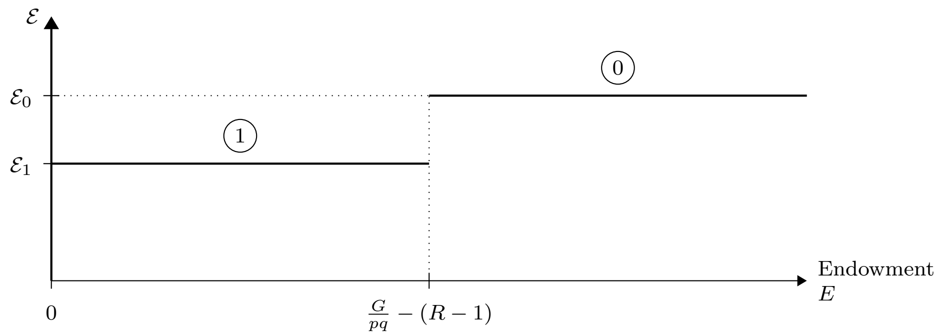
and its maximum is reached at $F = R - D$. This maximum financing capacity is always smaller than that of CoCos under Design 1, i.e., $(1-pq)(R-D) < (R-D) - p(R-R')$, as guaranteed by inequality (6).

We now analyze the optimal design of CoCo bonds in relation to the financing conditions of the banker. A comparison between CoCos of Design 0 and those of Design 1 reveals that the two types of CoCos have contrasting properties. The former allows for no moral hazard and delivers a higher value to the banker ($\mathcal{E}_0 > \mathcal{E}_1$) but also entails a greater agency rent and reduces the pledgeability of the cash flow to the external financiers. The latter, while generating only a lower value for not inducing efficient screening, concedes less agency rent to the banker and boosts the pledgeable income and the financing capacity of the security. As a result, the former will be adopted by a well-capitalized bank, for which the budget constraint is slack under a high E, and the latter by a capital-constrained bank that seeks to finance the loan portfolio and is ready to sacrifice efficient screening.

Proposition 2. *While a banker with $E < G/pq - (R-1)$ can only finance its loan portfolio with CoCos of Design 1 that avoids risk shifting at the cost of allowing for shirking, a banker with $E \geq G/pq - (R-1)$ will issue dilutive CoCos of Design 0 to achieve the first-best allocation. The banker's NPV as a function of the endowment is*

$$\mathcal{E}(E) = \begin{cases} \mathcal{E}_0 & \text{if } E \in [G/pq - (R-1), +\infty[\\ \mathcal{E}_1 & \text{if } E \in [0, G/pq - (R-1)[\,. \end{cases}$$

Figure 7: The bank's value and the banker's financial constraint



The figure plots the banker's choice of CoCo designs against her endowment. 0 is associated with CoCos that lead to no moral hazard. 1 is associated with CoCos that lead to shirking.

3.3 CoCo dilutiveness, financing capacity, and bank risks

We have shown in the last section that CoCos of Design 1 allows for a greater financing capacity and will be chosen by a constrained bank. We now establish that such CoCos are in fact all non-dilutive (proof in Appendix A.3).

Proposition 3. *All CoCos of Design 1 are non-dilutive, i.e.,* $\lambda < F/(R' - D)$*, whereas dilutive CoCos do not maximize the bank's financing capacity.*

Proposition 2 and 3 jointly show that non-dilutive CoCos can be seen as a 'necessary evil': the non-dilutive conversion is a design that constrained banks (those with $E < G/pq - (R-1)$) have to accept to make the financing feasible, even though such banks would prefer to issue CoCos of Design 0 to achieve a higher NPV if they were better capitalized.

Our model also reveals that the relationship between the dilutiveness of CoCos and bank risks can be subtler than the literature seems to suggest. First, CoCos need not

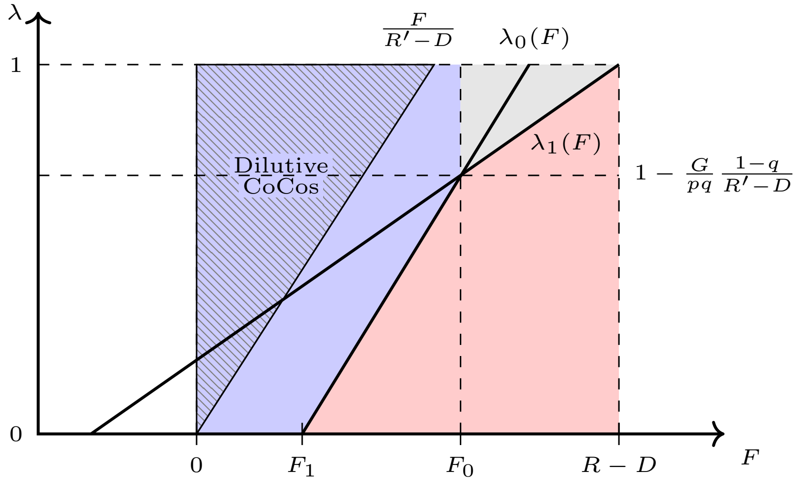


Figure 8: Bank risk and corresponding CoCo designs (illustration with $G/pq \leq R - R'$)

be dilutive to promote financial stability. To demonstrate this, we summarize the three CoCo designs in Figure 8, with a case $G/pq \leq R - R'$, and indicate with the hatched area the CoCo designs that are dilutive. Indeed, non-dilutive CoCos can also generate the first-best allocation (provided that the bank can be financed) as shown by the blue region that is not hatched. Second, dilutive CoCos can also be featured in designs associated with high risks. To see this, consider a case where the agency cost is high and $G/pq > (R - R')$, as shown in Figure 9. The main difference with respect to the case in Figure 8 is that now dilutive CoCos can be found in a subset (the red triangle in Figure 8) of Design 2 CoCos. We summarize these results in the following lemma (proof in Appendix A.4).

Lemma 4. *Depending the agency cost G, dilutive CoCos are not necessarily associated with only risk-free designs.*

- *When $G/pq \leq R - R'$, all dilutive CoCos are within Design 0, but Design 0 CoCos can also be non-dilutive (Figure 8).*

- *When $G/pq > R - R'$, in addition to those in Design 0, dilutive CoCos can also be in Design 2 (Figure 9).*

We emphasize that dilutive CoCos' impact on bank risks depends on the bank's financing condition. When the bank is well capitalized and the banker has a sufficient skin in the game, shirking is not attractive, and the first-best allocation can always be implemented with either dilutive or non-dilutive CoCos.[19] However, enforcing dilutive conversion on CoCos issued by a capital-constrained bank can lead to high risks. One can show that when G is sufficiently high and the banker faces major frictions in raising external financing, a constrained banker, if required to issue only dilutive CoCos, will choose Design 2 and engage in both shirking and risk shifting. We summarize the results in the following proposition. The proof is in Appendix A.5.

Proposition 4. *The impact of dilutive CoCos on risk-taking depends on the bank's equity capitalization:*

- *A well-capitalized bank, $E \geq G/pq-(R-1)$, can implement the first-best allocation, using either dilutive or non-dilutive CoCos, with a face value $F = F_0$.*

- *If a less capitalized bank, $E \in [pq(R' - D) - (R' - 1), G/pq - (R - 1)[$, is required to issue only dilutive CoCos, it will use dilutive one of Design 2 when the friction*

[19] In fact, if $E > 1 - D - F_1$, the banker can fund the loan portfolio by issuing CoCos (F, λ) with $F \in [0, F_1]$ and $\lambda \in [0, 1]$: no restriction needs to be placed on the conversion ratio to keep the bank risk-free.

of raising external financing is high, $G/pq > (R - R') + pq(R' - D)$. *Under the high agency cost case, the banker's NPV as a function of her endowment is*

$$\mathcal{E}(E) = \begin{cases} \mathcal{E}_0 & \text{if } E \in [G/pq - (R-1), +\infty[\\ \mathcal{E}_2 & \text{if } E \in [pq(R'-D) - (R'-1), G/pq - (R-1)[\\ 0 & \text{if } E \in [0, pq(R'-D) - (R'-1)[\,. \end{cases}$$

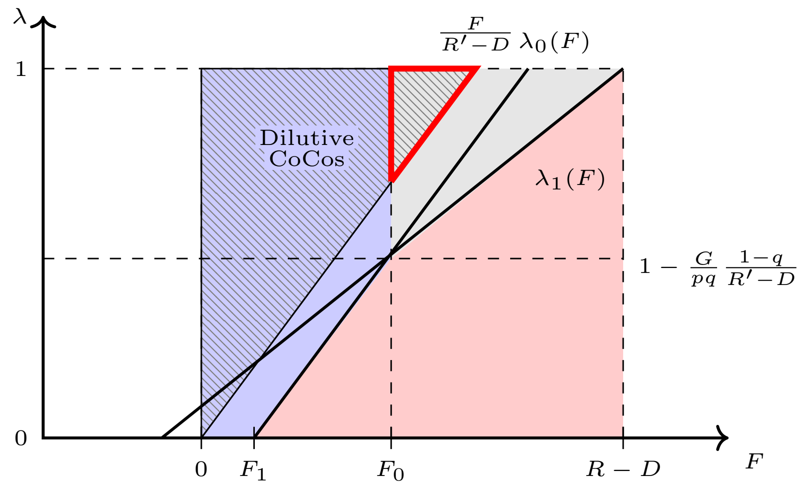


Figure 9: Bank risk and corresponding CoCo designs (illustration with $G/pq > R - R'$)

Our result reveals that CoCos are no substitute to bank equity. Rather, CoCos' designs and their impacts on bank risks crucially depend on the equity capitalization of banks. Indeed, depending on banks' capitalization, the prevalence of non-dilutive CoCos has two possible interpretations. When banks are sufficiently capitalized, non-dilutive designs should not raise any concerns per se, because they can deliver the first-best risk level. An alternative interpretation, which considers non-dilutive designs less favorably, is that capital-constrained banks use such CoCos to stretch the size of their balance sheets but only at the cost of allowing for a degree of risk taking (i.e., the lack of efficient screening). Under this interpretation, a case can be made to further increase bank equity to realize the full potential of CoCos in promoting financial stability. At any rate, we emphasize that CoCos' designs, and their implications for bank risk, cannot be analyzed independently of a bank's funding situation.

Finally, given the popularity of PWD CoCos, it can be useful to take a closer look at such securities through the lens of our model. In our setting, PWD CoCos with full and permanent write-off upon conversion are those CoCos with $\lambda = 0$. Two important remarks are in order. First, such PWD CoCos can be found both in Design 0 and Design 1, which re-affirms our observation that non-dilutive CoCos can still be used to implement the first-best allocation when the bank is sufficiently capitalized. Second, while PWD CoCos with full and permanent write-down features do not maximize the financing capacity of CoCos, they may still allow for a greater financing capacity than dilutive CoCos and be preferred by an equity constrained bank. We conclude by stating the following result (proof in Appendix A.6).

Corollary 1. *When the bank is sufficiently capitalized, $E > G/p + (R' - D) - (R - 1)$, a PWD CoCo is risk free (Design 0) for it ensures no moral hazard action from the banker. When such a PWD CoCo is risky (Design 1), it generates a higher financing capacity than equity conversion CoCos within Design 0 if*

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

in which case, the PWD CoCo will be preferred by banks with equity capital $E \in [p(R - D) - (R - 1), G/pq - (R - 1)]$.

4 CoCos vs. other forms bank regulatory capital

In this section, we compare CoCo bonds to two alternative classes of securities that are considered as regulatory capital of banks: subordinate debt, Section 4.1, and non-voting shares, Section 4.2. For each of the two classes, we first investigate its equilibrium design given the bank's equity capitalization, and then compare it with CoCo's in terms of the bank value that can be achieved. We show that there exist ranges of capitalization E where CoCos strictly dominate the other two securities, and that CoCos perform as well as they do for other values of E. So even though CoCos are no substitute to equity, based on the comparisons, we believe that CoCos should well qualify as regulatory capital for it can outperform other securities in the regulatory capital stack.[20]

CoCos' advantage comes from their flexibility in designs, which can contribute to either better risk management at the bank or allowing for more financing opportunity. Compared to subordinated debt that entails a constant repayment across all non-bankruptcy states (R' and R in our setting), CoCos allow for a reduction of the payout to external financiers in the R'-state and can therefore better prevent risk shifting. Compared to non-voting shares that allocate a fixed fraction of residual cash flow to external financiers across R'- and R-states, CoCos can allow a lower payout to the financiers in the R-state and can better preserve the banker's incentive to screen loans, making it feasible to implement a risk-free bank for a wider range of E. We now present the formal analysis.

[20]The Additional Tier 1 status of CoCos can also be justified because non-voting shares can be considered as Tier 1 capital if they differ from common stock only in terms of voting rights,

4.1 Subordinated debt

A subordinated debt contract is characterized by its face value that we denote by B. To parallel with CoCo bonds, we first analyze how the banker's moral hazard actions relate to the design of the subordinated debt. In Appendix A.7, we prove the following results.

Lemma 5. *A subordinated debt contract with face value $B \leq F_0$ induces no moral hazard action from the banker, and the risk-free debt can be sold for $P_0^D(B) = B$. When $B > F_0$, subordinated debt leads both to shirking and risk shifting, which makes it risky and have an equilibrium price $P_2^B = (1 - pq)B$.*

Lemma 5 shows that the (inflexible) design of subordinated debt contract cannot induce a strategy of partial risk-taking from the banker (i.e., shirking but no risk shifting). Only the strategy with no moral hazards or the one with both moral hazards is feasible. This is because the banker's risk shifting incentives increase in the face value B, due to her limited liability. On the other hand, at a low B for which the banker receives more in the R-state, the value destroyed by shirking would be greater than the private benefit, so the banker screens the loan portfolio and avoids such a loss.

In terms of financing capacity, risk-free subordinated debt can at most allow the banker to raise $F_0 = (R - D) - G/pq$, whereas risky subordinated debt can raise up to $(1 - pq)(R - D)$. Risky debt has a higher financing capacity if and only if

$$\frac{G}{pq} > pq(R - D), \tag{14}$$

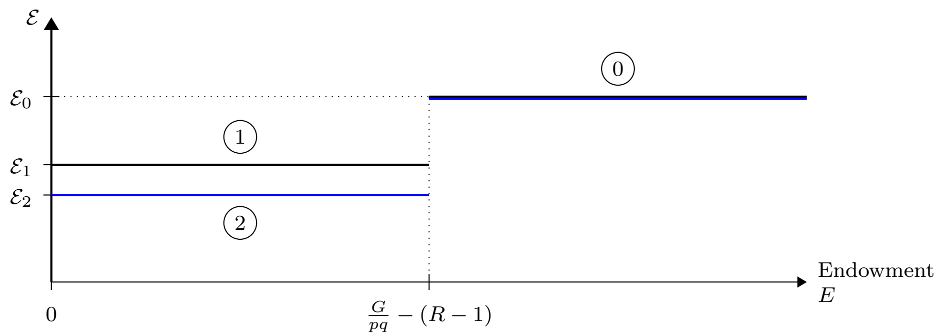
in which case it will be chosen by an equity constrained bank. Otherwise, risky subordinated debt is always dominated by risk-free debt. Formally, we have the following lemma on how equilibrium design of subordinated debt contract depends on the bank's equity capitalization.

Lemma 6. *When $G/pq > pq(R-D)$, risky subordinated debt has a higher financing capacity than risk-free debt. A bank with equity $E < G/pq-(R-1)$ can only be financed by risky subordinated debt, which leads to both shirking and risk shifting. A better capitalized bank with $E \geq G/pq-(R-1)$ will issue risk-free subordinated debt and take no moral hazard action. The banker's NPV as a function of her endowment is*

$$\mathcal{E}(E) = \begin{cases} \mathcal{E}_0 & \text{if } E \in \left[\frac{G}{pq}-(R-1), +\infty\right[\\ \mathcal{E}_2 & \text{if } E \in \left[0, \frac{G}{pq}-(R-1)\right[. \end{cases}$$

We show the comparison between CoCo bonds and subordinated debt in Figure 10, with the subordinated debt in blue and CoCo bonds in black. A well capitalized bank with $E \geq G/pq-(R-1)$ will be risk free whether the bank raises external financing with CoCos or subordinated debt. When the bank is less well capitalized and has to issue risky subordinated debt to cover its financing need, however, the banker can only obtain $\mathcal{E}_2$. In contrast, the non-dilutive CoCo has a maximum financing capacity greater than that of risky debt, i.e., $P_1^C > P_2^B$. So the bank can also be financed by CoCo bonds, in which case the higher value $\mathcal{E}_1$ is attainable by the banker. This reveals that CoCos dominate subordinated debt for an undercapitalized bank.

Proposition 5. *For a undercapitalized bank with $E < G/pq-(R-1)$, non-dilutive CoCos dominate subordinated debt.*



The figure plots the incremental equity value between CoCos and subordinated debt. The black line represents the NPV achieved using CoCo bonds, and the blue line the one achieved using subordinated debt. 0 is associated with contracts that lead to no moral hazard. 1 is associated with contracts that lead to shirking. 2 is associated with contracts that lead to shirking and risk shifting.

Figure 10: The banker's value and her financial constraint: CoCos vs subordinated debt.

4.2 Non-voting shares

When the banker raises external financing by issuing non-voting shares, the design parameter of the security is the fraction α of the payoff given to outside equity holders. We focus on non-voting shares because we assume the new equity holders will not be given any rights on the private benefit from shirking, G. In Appendix A.8, we prove the following results on how the banker's risk-taking actions depend on α.

Lemma 7. *A risk-free bank can be financed with non-voting shares if* $\alpha \leq 1 - G/p(R - R')$*, in which case the offering of the shares allows the banker to raise* $P_0^S = \alpha(R - D)$*. For* $\alpha > 1 - G/p(R - R')$*, the issuance of non-voting shares leads to shirking but no risk shifting, and the shares can be sold for* $P_1^S = \alpha[R - D - p(R - R')]$*.*

The risk-taking incentive is eliminated by the payoff structure of equity, as the rent to new shareholders is a fixed fraction of the residual value after debt repayments. Hence, there is no wealth transfer between the new and incumbent shareholders, and no conflict of interests arises when it comes to shifting risk to the deposit insurance fund.

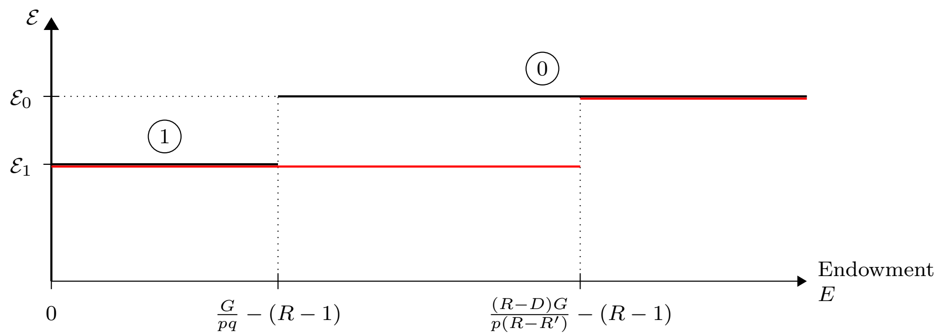
To maintain the banker's incentives to screen the loan portfolio, the maximum financing capacity of non-voting shares must be $[1 - G/p(R - R')]\,(R - D)$. In contrast, if shirking is allowed, such a capacity raises to $R - D - p(R - R')$. The following lemma describes how the issuance of non-voting shares depends on the equity capitalization of the bank.

Lemma 8. *The price of non-voting shares of Design 0 is always lower than the one of Design 1. Only an unconstrained banker with $E \geq (R - D)G/p(R - R') - (R - 1)$ can achieve the first-best risk level by issuing non-voting shares. A banker with $E < (R - D)G/p(R - R') - (R - 1)$ has to issue non-voting shares $\alpha > 1 - G/p(R - R')$, which triggers shirking. The banker's NPV as a function of her endowment is*

$$\mathcal{E}(E) = \begin{cases} \mathcal{E}_0 & \text{if } E \in \left[\frac{(R-D)G}{p(R-R')} - (R-1), +\infty\right[\\ \mathcal{E}_1 & \text{if } E \in \left[0, \frac{(R-D)G}{p(R-R')} - (R-1)\right[. \end{cases}$$

We compare CoCo bonds to non-voting shares in Figure 11, with CoCo bonds in black and non-voting shares in red. Neither security encourages the banker to engage in risk shifting. The key takeaway is that CoCo bonds perform better in implementing the first-best allocation. In particular, if the bank's endowment E is between $G/pq-(R-1)$ and $(R-D)G/p(R-R')-(R-1)$, issuing CoCos instead of non-voting shares discourages shirking and generates a higher value to the banker. The following proposition summarizes the result.

Proposition 6. *For $E \in [G/pq - (R - 1), (R - D)G/p(R - R') - (R - 1)[$, CoCos dominate non-voting shares.*



The figure plots the incremental equity value between CoCos and non-voting shares. The black line represents the NPV achieved using CoCo bonds, and the red line the NPV achieved using non-voting shares. 0 is associated with contracts that lead to no moral hazard. 1 is associated with contracts that lead to shirking. 2 is associated with contracts that lead to shirking and risk shifting.

Figure 11: The banker's value and her financial constraint: CoCos vs non-voting shares.

Intuitively, equity is not an effective security to punish shirking, for it allocates a fixed fraction of wealth to external financiers across different levels of cash flows. A small such fraction, on the one hand allows the banker to keep a large part of cash flow in all the states, which offsets the loss of private benefit from shirking, on the other it reduces the pledgeable income for outside financiers. In comparison, a CoCo bond is more flexible and allows the contract to be finely tuned on the contingent states by adjusting the face value, F, and the conversion fraction, λ. A CoCo bond can promise a high payoff to incumbent equity holder in the R-state to induce screening but punishes shirking with a small payoff to the banker upon its conversion in the R'-state. The latter not only corrects ex-ante incentives but also leaves a higher pledgeable income. To conclude, CoCo bonds are better at eliminating shirking incentives than non-voting shares for undercapitalized banks.

5 CoCos and bank risk-taking: loan-level evidence

In this section, we test the main conclusions from our theory using loan-level data. The empirical literature has been focussing on the determinants of CoCo issuances. Fajardo and Mendes (2020) show, in emerging economies, that banks with higher regulatory capital ratios and lower loan levels are more likely to issue CoCos. In Europe (in particular, the European Economic Area), Goncharenko et al. (2021) find that banks with lower asset volatility are more likely to issue CoCos. This result is also supported by Williams et al. (2018), who find that most of CoCo issuances were done by banks characterized by high systematic risk from global data. The common denominator of these studies is that 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 pin down the post-CoCo issuance behavior of a bank. Only few papers test empirically whether the risk-taking behavior is different between of CoCo issuers and non-issuers, and they provide mixed results regarding how CoCos impact the volatility of bank assets. Berg and Kaserer (2015) and Hesse (2016) investigate the pricing of CoCo bonds and show that investors discount the fact that CoCos exacerbate agency problems. As far as we know, our empirical analysis is the first to explore, using loan data, how the inclusion of CoCos in the capital structure affects banks' risk appetite on lending.

More recently, Avdjiev et al. (2020) 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 compare the impacts of issuance between two different types of CoCo bonds: principal write-down (PWD) and equity conversion. They find that the issuance of equity conversion Co-

Cos significantly reduce a bank's 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. Hau and Hrasko (2018) also use CDS spreads to test the effect of CoCo issuance announcement on bank default risk. However, their results show that PWD CoCos outperform equity-conversion CoCos, and on average, PWD CoCos reduce default risk in a similar fashion as common equity.

The empirical challenge of all these studies is that it is hard to separate the two opposing 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. Besides, common equity may not be the appropriate benchmark security to test the risk shifting incentives created by CoCos. The reason is that CoCos are not in CET1 capital category, and banks are not supposed to replace common equity with CoCos in the first place.[21] We address this challenge by focussing directly on the effect of CoCo issuance on a bank's risk appetite, rather than on its credit worthiness, and comparing the lending behaviour of CoCo issuers vs non-issuers. Such a comparison allows banks to choose their preferred capital structure and relax the assumption on any specific security being the substitute of CoCos.

In our tests, we use loan spreads from the syndicated loan market. Because a syndicated loan is issued by multiple banks, our setup allows us to compare the risk-taking

[21] From Basel III, the capital requirement of Common Equity Tier 1 ratio is lower than the one of Tier 1 ratio.

behaviour of different banks when lending to the same borrower. To be specific, because multiple lenders participate in one syndicated loan package, the financing needs of an individual borrower can be stably supplied without the concern of a change in lending policies of a specific lender, which allows to control for the demand of funding over the time. Then, we investigate how the risk appetite of a bank changes regarding its lending activity in the syndicated loan market by comparing the loan spreads from CoCo issuers versus 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 are collected from Bloomberg, from which we have a total of 851 CoCos issuances occurred from 2009 to 2019. Our sample excludes observations from banks other than 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.[22] 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 the update

[22] 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%.

of regulation. Within those G-SIBs, we find that most banks have never issued any equity-conversion CoCo bonds, and relied on PWD CoCo bonds instead. In Table 3, we collected all the CoCo issuances by G-SIBs.

A CoCo bond with a lower conversion price than the market stock price at the conversion date is dilutive and transfers wealth to their holder upon conversion. In contrast, if the stock price is lower than the conversion price, a CoCo bond is non-dilutive, and the conversion is in favour of 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 corresponds to the case with a zero conversion ratio.

Table 3 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. In Panel B, only one bank from non-UK countries issued equity-conversion CoCos, 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, conversion prices of the banks except HSBC are significantly higher than the banks' 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 one of the most important markets for worldwide corporate financing (Ivashina, 2009). The data source of syndicated loans is Reuters' DealScan database. The advantage of using the syndicated loan data is that a firm borrows from a group of lenders instead of only one: even if some of the lenders change their lending policy and refuse to finance a firm, that firm could still borrow from the rest of the syndicate. This makes the syndicated loan market attractive and provides a stable funding supply for firms. More importantly, loan

Table 3: Active CoCos from G-SIBs

The table summarizes AT1 CoCos issued by G-SIBs from 2013 to 2019. Equity-conversion CoCos are predominantly issued by banks in the UK. 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.

(a) Panel A: UK banks

G-SIBs(Parent)	Active CoCos	Weight in Tier 1 capital	PWD	Conversion Price.
HSBC	13	13.59%	N	£2.70
Barclays	11	19.57%	N	£1.65
Lloyds	7	17.37%	N	£0.63
RBS	3	11.32%	N	$2.28
SC PLC	4	12.80%	N	£5.96

(b) Panel B: Non-UK banks

G-SIBs(Parent)	Active CoCos	Weight in Tier 1 capital	PWD	Conversion 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	-

spreads change across different facilities within the same package taken by a firm. That is, banks participating in the same package do not necessarily share the same pricing strategy, which arguably reflects their risk attitude.

A drawback of using syndicated loan market data is that on average two-thirds of banks' share of volumes are not all recorded. That limits the extent of our investigation regarding the total volume of loans a bank lends every year.

We aim at tracking the pricing strategy of banks to measure how much a bank asks for compensating the risk it bears. To do so, we use loan spreads, which are available from DealScan, to capture the pricing difference. We keep a syndicated loan facility only if its facility amount is not missing. 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. Murfin (2012) reports that it could take a bank more than three months to approve a term sheet, and therefore he sets the contracting date as 90 days prior to the start date. We adopt his approach in our robustness checks.

Finally, 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 used to be G-SIBs. The list of G-SIBs is in Table 7 in Appendix B. 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.[23] We set

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

the years 2010-2011 in the sample to be the pre-regulation period and 2012-2019 as the post-regulation period. We exclude 2011 from the post-regulation period because the release of BCBS 2011 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 and report the summary statistics of the final sample in Table 4. For loan characteristics, we use All-in-drawn spreads 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 4, 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

Table 4: 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

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 expect banks that have issued CoCo bonds to tighten their lending activities by charging higher spreads.

Loan spreads reflect both demand- and supply-side effects in the loan market. Our test concentrates on the lending strategies of fund suppliers, so the demand for funds must be controlled. Our methodology follows Khwaja and Mian (2008) and Acharya et al. (2018), who control for the loan demand and bank characteristics. In addition, we assume the loan demand for each borrower is constant within one year so we use borrower-year fixed effects to control for the time-varying loan demands for each firm and the cross-section of firms.

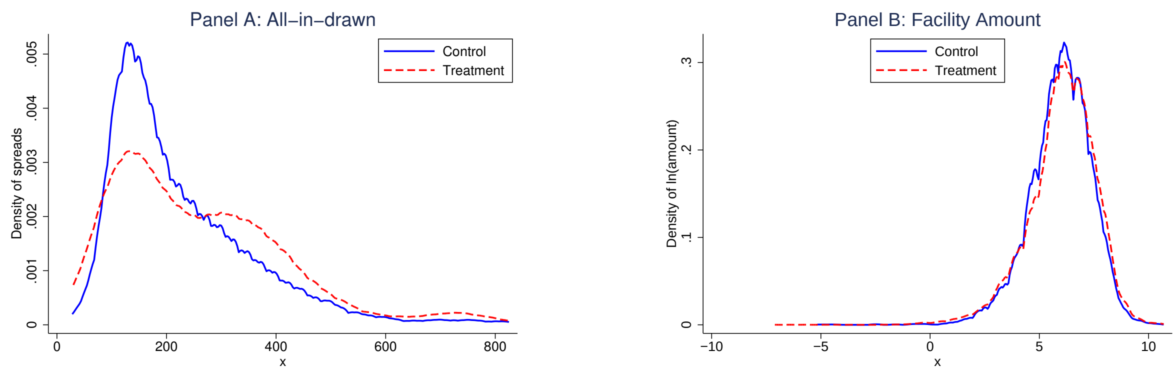
We are upfront on the fact that a tightened lending strategy can result in both a reduction in loan volumes and an increase in loan spreads, the two being not mutually exclusive. In other words, a more "risk-averse" bank invests less into risky loans and asks for a higher return to compensate for risk. 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 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 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 the treatment and control groups of banks are similar as per the amount of lent 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.

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.



Our baseline specification is

$$Spread_{i,b,l,t} = \alpha_{b,t} + \beta_0 Treat_l + \beta_1 DiD_{l,t-1} + \gamma_1 X_{l,t-1} + \gamma_2 Y_{i,t} + \epsilon_{i,b,l,t}, \tag{15}$$

with borrower-year fixed effects to control for the time-variant demand change. In (15), 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 advantage 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 are not related to banks' risk preferences, focussing on the loan spreads isolates banks' risk appetite at the contracting date.

5.3 Results

Table 5 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 effects model allows us to observe the difference in lending strategies when banks lend to an average firm. While the demand for loans is controlled, 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 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 supports our theory that non-dilutive CoCo contributes 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 cus-

Table 5: Baseline model

We report 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 the 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

tomer deposits are statistically significant and their negative sign supports our theory. That is, banks with more deposits face severer agency conflicts (risk shifting incentives), so they tend to prefer risky investments by relaxing their lending standards, or equivalently, by requiring 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 suggests 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 Murfin (2012). The 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 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's risk appetite due to the adoption of CoCo should be more clearly reflected in the offered loan spreads.

The results in Table 6 deliver 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 happen between the contracting date and the 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

Table 6: Robustness check

We report the empirical test of the baseline Diff-in-Diff model. The difference from Table 5 is the starting date of each facility is the contracting date, following Murfin (2012). 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

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 banker 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 limiting the amount payable to CoCo investors after the bank has made losses and triggered conversion preserve existing shareholders' value and prevents risk shifting. Such a design, however, compromises the shareholders' incentives to properly screen loans in the first place. 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 risk shifting 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 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, CoCos that fully address both moral hazard problems can still be attainable when banks are better capitalized. Our model, therefore, shows that CoCos are no substitute for banks' equity capital. Rather, the effectiveness of CoCos in preventing risk-taking depends on banks' equity capitalization. Our theoretical prediction also 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. But we are not entirely pessimistic and consider non-dilutive CoCos necessarily inducing risk-taking either, because our model reveals that non-dilutive CoCos are not necessarily related with high risks, and 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, and whether that is attainable crucially depends on the equity capitalization of banks.

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A Proofs of lemmas, propositions, and corollaries

A.1 The banker's maximization program

For risk levels $i \in \{0, 1, 2\}$, the total expected cash flow available to the banker and the external financiers, denoted by CF_i, is respectively

$$\begin{aligned} CF_0 &= R - D \\ CF_1 &= pR' + (1-p)R - D + G \\ CF_2 &= (1-pq)(R-D) + G. \end{aligned}$$

Because external financiers break even, their expected cash flow is the price $P_i(\theta^j)$ of the security issued by the bank, and the expected cash flow to the banker is

$$\Pi_i(\theta^j) = CF_i - P_i(\theta^j).$$

Because $K_i(\theta^j) = 1 - D - P_i(\theta^j)$, the banker's NPV for risk level i is

$$\mathcal{E}_i = \Pi_i(\theta^j) - K_i(\theta^j) = CF_i - P_i(\theta^j) - \left[1 - D - P_i(\theta^j)\right] = CF_i - 1 + D.$$

Therefore, the banker's NPV for risk level i is $\mathcal{E}_i = CF_i - 1 + D$, independently of the specific security issued.

A.2 Proof of Proposition 1

To analyze how the equilibrium CoCo design depends on the bank's equity capitalization, we calculate the maximum financing capacity of the three CoCo designs. First, note that CoCos with Design 0 have a maximum financing capacity of

$$F_0 = (R - D) - \frac{G}{pq},$$

because such CoCos are risk-free and reaches the maximum financing capacity when F is set to the highest possible value while not violating the banker's incentive constraints. On the other hand, CoCos with Design 1 have a maximum financing capacity of

$$(R - D) - p(R - R').$$

To see this, we separate the contracts under Design 1 into two cases: $F \in [F_2, F_0[$ and $F \in [F_0, R - D]$, where both allow the banker to raise $P_1^C = (1 - p)F + p(R - D)\lambda$. However, the banker faces two different requirements on λ between these two cases. In the first case, $F \in [F_2, F_0[$ and $\lambda < \lambda_0$, which leads to

$$P_1^C < (1 - p)F + pF - p(R - R') + G,$$

where the right-hand-side is lower than F as $G < p(R - R')$ from the assumption in (3). That means the maximum amount raised in such a case is lower than the financing capacity of Design 0 (risk-free). Such a contract is always dominated by Design 0 due to a lower financing capacity and equity value. Therefore, this case becomes irrelevant.

In the case $F \in [F_0, R - D]$, one can substitute $\lambda_1(F)$ into the expression of $P_1^C(F, \lambda)$ from Lemma 2 and notices that the resulting expression monotonically increases in F. The maximum financing capacity is such that

$$R - D - p(R - R') > R - D - \frac{G}{pq},$$

which is equivalent to Assumption 1. Note that $R - D - G/pq$ is the maximum amount raised by Design 0. So, the case with $F \in [F_0, R - D]$ and $\lambda < \lambda_1$ is the only one not dominated by Design 0.

Finally, CoCos with Design 2 have a maximum financing capacity of

$$(1 - pq)(R - D),$$

because the price of such CoCos is $P_2^C = (1 - pq)F$ and the upper bound of F is $R - D$. The result that Design 1 allows the banker to raise a higher amount than Design 2, or

$$(1 - pq)(R - D) < R - D - p(R - R').$$

follows directly from inequality (6).

A.3 Proof of Proposition 3

By Lemma 2, a CoCo bond of Design 1 features $F \geq F_1$ and $\lambda \leq \min\{\lambda_0(F), \lambda_1(F)\}$. First note that we only need to focus on those contracts with $F > F_0$ and $\lambda < \lambda_1(F)$, because contracts of Design 1 with $F \in [F_1, F_0]$ are dominated by Design 0 CoCos with a face value F_0. That is,

$$\lambda_0(F_1)(R' - D) = R' - D - \frac{G}{pq} < F_0.$$

For a contract with $F \in]F_0, R - D]$, upon conversion the CoCo holders receive at most

$$\lambda_1(F)(R' - D) = (1 - q)F - (R - R') + q(R - D),$$

which is smaller than F because $q(R - D) - (R - R') < qF$ for $F > F_0$. To prove the inequality, one can simply substitute in the expression of F_0 and verify that

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

The right-hand-side is less than zero by inequality (2). Hence, all the CoCo of Design 1 are non-dilutive.

A.4 Proof of Lemma 4

A CoCo bond is defined dilutive if it transfers wealth from equity holders to CoCo holders. In the R'-state, such a bond generates a payoff to its CoCo holders $\lambda(R' - D)$ upon conversion, which is greater than its face value F. So, a CoCo is dilutive only if

$$\lambda > \frac{F}{R' - D}.$$

Since $\lambda \in [0, 1]$, the face value of a dilutive CoCo should follow

$$F < R' - D,$$

which sets an upper bound of F.

When $G/pq \leq R - R'$, the upper bound of the face value is smaller than F_0

$$R' - D \leq R - D - \frac{G}{pq}.$$

Given that F_0 is the upper bound of F for Design 0 CoCos and $\frac{F}{R'-D} > \lambda_0$, all the dilutive CoCo bonds are within Design 0.

On the other hand, when $G/pq > R - R'$, the upper bound of F

$$R' - D > R - D - \frac{G}{pq}.$$

That means, dilutive CoCos can be designed with $F > F_0$. For $F > F_0$, as $F/R' - D > \lambda_0(F) > \lambda_0(F)$, dilutive CoCos fail to avoid risk shifting and are within Design 2.

Next, we show that not only dilutive CoCos can avoid shirking and risk shifting. In fact, there should always exist at least one non-dilutive CoCo for each $F \in [0, F_0]$ that are within Design 0. That is because the lower bound of λ for dilutive CoCos is always greater than the upper bound of λ in Design 1. The latter is

$$F - (R - R' - G/P)/(R' - D) < F/(R' - D),$$

since $R - R' > G/p$ in inequality (2).

A.5 Proof of Proposition 4

We check whether CoCos of Design 2 can raise more than the ones of Design 0. If not, the banker would prefer dilutive CoCos with $F \leq F_0$ since they provide greater financing capacity than CoCos of Design 2. As we have shown in Lemma 4, the upper bound of F in a dilutive CoCo is $R' - D$. Therefore, the maximum financing capacity for a dilutive

CoCo of Design 2 is $(1-pq)(R'-D)$. Note that $(1-pq)(R'-D) > R-D-G/pq$ only if

$$\frac{G}{pq} > R - R' + pq(R-D).$$

When $R-R'+pq(R-D) > \frac{G}{pq} > R-R'$, although dilutive CoCos of Design 2 are feasible, the banker issues only CoCos of Design 0 if she is enforced to issue dilutive CoCos, because the CoCos of Design 0 offer both higher equity value and greater financing capacity. In sum, dilutive CoCos of Design 2 are preferred only if $G/pq > R - R' + pq(R-D)$, in which case being dilutive is not a sufficient condition for implementing the first best allocation.

Next, we check the existence of $G/pq > R - R' + pq(R-D)$. In inequality (2), $G/pq > (R-R')/q$, so the case of preferred dilutive CoCos of Design 2 exists if

$$R - R' > \frac{pq^2}{1-q}(R'-D).$$

Because the last inequality holds when D is close to R', due to the continuity, this case must hold for the neighborhood of the parameters.

As for the initial endowment, the bank issuing dilutive CoCos of Design 0 can raise at most F_0. So, a bank needs

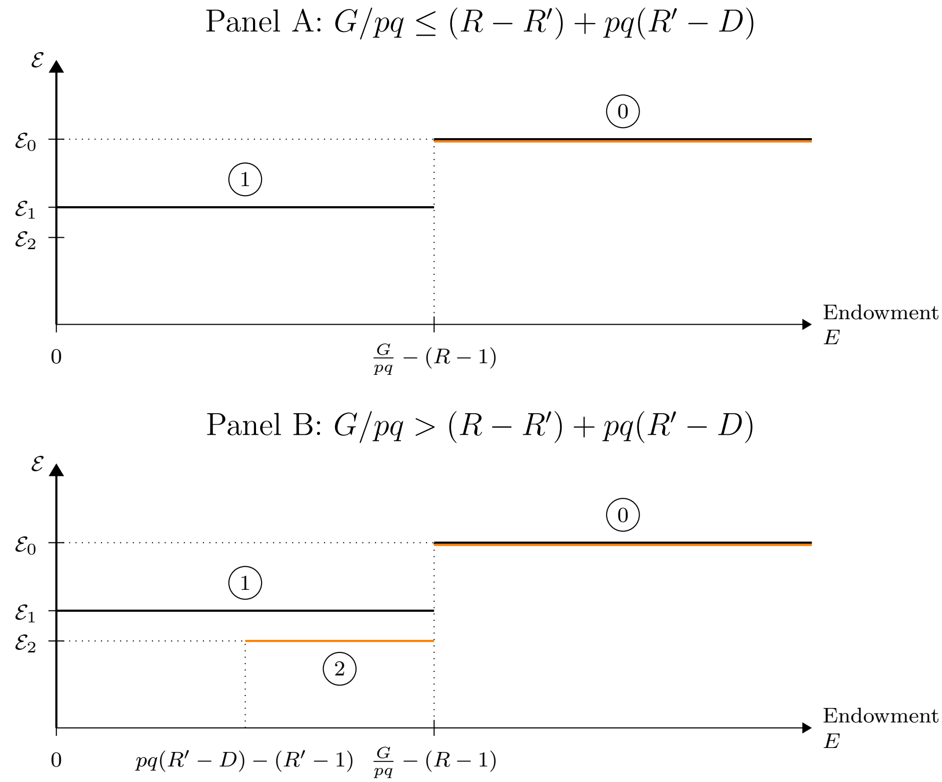
$$1 - D - F_0 = \frac{G}{pq} - (R-1)$$

to implement the first best. When $E < G/pq - (R-1)$ and$\frac{G}{pq} > R - R' + pq(R-D)$, the banker would try to finance the project by issuing dilutive CoCos. In this case, she would raise at most$(1-pq)(R'-D)$. Namely, a bank would need at least

$$E \geq pq(R'-D) - (R'-1)$$

to finance the project with dilutive CoCos of Design 2. Given $\mathcal{E}_0 > \mathcal{E}_2$, a bank prefer Design 0 to Design 2 whenever the former is feasible. Therefore, a dilutive CoCo of Design 2 is issued only if

$$E \in [pq(R'-D) - (R'-1), G/pq - (R-1).$$



The figure plots the incremental equity value between dilutive and non-dilutive CoCos. The black line represents the NPV achieved by non-dilutive CoCos, and the orange line the NPV achieved by dilutive CoCos. 0 is associated with contracts that lead to no moral hazard. 1 is associated with contracts that lead to shirking. 2 is associated with contracts that lead to shirking and risk shifting.

Figure 13: Comparison between dilutive and non-dilutive CoCos.

A bank with $E < pq(R'-D)-(R'-1)$ cannot be financed by dilutive CoCos.

The comparison between dilutive and non-dilutive CoCos regarding the financing capacity and the banker's NPV are illustrated in Figure 13.

A.6 Proof of Corollary 1

Two different types of PWD CoCos exist in our model: the contracts implementing first-best allocation (Design 0) and those implementing risk level 1 (Design 1). The former is feasible for $F \in [0, F_1]$ and allows the bank to raise at most F_1. The banker needs to have an endowment

$$E > 1 - D - F_1 = G/p + (R' - D) - (R - 1)$$

to keep the bank risk-free.[24]

On the other hand, Design 1 PWD CoCos of have a greater financing capacity than Design 0. Note that for Design 1 PWD CoCos the upper bound of F is $R - D$. The banker, therefore, can raise at most $(1 - p)(R - D)$ with $\lambda = 0$, which exceeds the maximum financing capacity of Design 0 CoCo, F_0, if and only if $p(R - D) < G/pq$. To finance the bank with such PWD CoCos, the required endowment is

$$E > p(R - D) - (R - 1).$$

A.7 Proof of Lemma 5

When subordinated debts are issued to finance the project, the expected payoffs for the different risk levels to the banker are respectively

$$\begin{aligned}
\Pi_0^B &= R - D - B, \\
\Pi_1^B &= p \max\{R' - D - B, 0\} + (1 - p)(R - D - B) + G, \\
\Pi_2^B &= (1 - pq)(R - D - B) + G.
\end{aligned}$$

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 inequality (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 inequality (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

[24] Note though this type of PWD CoCos provides a smaller financing capacity than those Design 0 CoCos with a face value F_0.

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.

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 inequality (2). Therefore, Design 1 cannot be feasible.

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 inequality (2), we can conclude the lower bound on B is F_0.

A.8 Proof of Lemma 7

The expected payoffs to the banker for the different risk levels with equity financing are respectively

$$\begin{aligned}\Pi_0^S &= (1-\alpha)(R-D),\\ \Pi_1^S &= (1-\alpha)[(1-p)(R-D)+p(R'-D)]+G,\\ \Pi_2^S &= (1-\alpha)(1-pq)(R-D)+G.\end{aligned}$$

In the following, we denote two thresholds for α by

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

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 inequality (6), then Design 0 is feasible for $\alpha < \alpha_0$.

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 $R'-D-(1-q)(R-D) > 0$, which is equivalent to (6).

For Design 2 to be feasible, it should be $\Pi_2^S > \Pi_0^S$ and $\Pi_2^S > \Pi_1^S$. However, we showed that the first is equivalent to $\alpha > \alpha_1$ and the second is never true for inequality (6).

B Additional tables

Table 7 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 7: 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	