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Nondilutive CoCo Bonds: A Necessary Evil?

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Banks predominantly issue nondilutive CoCos, contrary to the suggestion that CoCos should be dilutive to reduce risk-taking. In an agency model of two moral hazards, we show that, although dilutive CoCos deter ex ante risk-taking and prevent banks from being undercapitalized, penalizing shareholders of a distressed bank with dilution leads to ex post risk-shifting. CoCos' design and risk implications depend on bank capitalization: equity-constrained banks prefer nondilutive CoCos because they maximize the financing capacity by tackling ex post risk shifting only. Nondilutive CoCos can be used to implement the constrained social optimum for highly leveraged banks, and regulators can induce appropriate CoCo designs with capital regulations. (*JEL* G21, G28)

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On March 19, 2023, Credit Suisse faced imminent default and was saved through a regulator-brokered takeover by UBS. A crucial aspect of the agreement entailed the complete write-off of SFr 16bn of Additional Tier 1 (AT1)

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bonds issued by Credit Suisse, which transferred value from the AT1 bond investors to Credit Suisse's shareholders. Those AT1 bonds issued by Credit Suisse were contingent convertible bonds (CoCos) that, as became painfully clear to their investors, have the unique feature of being junior to a bank's existing common equity. In this paper, we empirically document the prevalence of such CoCos and explore the theoretical rationale behind their design.

CoCos, a new addition to the regulatory capital stack in the Basel III framework, have contingent payoffs based on a bank's Common Equity Tier 1 (CET1) ratio. CoCos pay out like regular bonds unless the bank's CET1 ratio falls below a prespecified level. At that point, equity-conversion CoCos are converted into equity at a preset price, while principal-write-down (PWD) CoCos, like those issued by Credit Suisse, face partial or full write-off. Classified as AT1 capital, CoCos are designed to absorb unexpected losses for retail depositors and reduce bank shareholders' incentives for excessive risk-taking.

With the AT1 designation, CoCos became a significant form of regulatory capital. Over the period 2009-2020, banks outside of the United States issued CoCos with a total face value of US$ 580bn, with Global Systemically Important Banks (G-SIBs) alone contributing about 50% of the total amount.[1]

CoCos were promoted by researchers and regulatory authorities because they are 'bailed in' when a bank's common equity buffer drops, thus overcoming banks' reluctance to recapitalize themselves and avoiding any recapitalization by the public authorities—potentially with taxpayers' money and distorting banks' risk-taking incentives—but also for their potential to punish bank shareholders' risk-taking by diluting their claims upon CoCos' conversion. While the basic design of CoCos unambiguously adds to the loss-absorbing capacity of banks, whether CoCos can 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 prespecified threshold. Such securities, arguably, appear to provide little incentive for bank shareholders to limit their risk-taking and avoid triggering the conversion. Yet, in the majority of cases, CoCos issued by G-SIBs are PWD CoCos, as shown by panel A of Table 1.

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. However, the recent COVID crisis and its instantaneous (albeit short-lived) aggregate negative impact on the stock market revealed that such equity-conversion CoCos are unlikely to be dilutive either. As illustrated in panel B of Table 1, upon the shock, the market prices of banks'

[1] For example, CoCos make up about 15% of U.K. G-SIBs' Tier 1 capital. The main exception is the United States, since CoCos have not earned favorable regulatory treatment and banks have not joined the rest of the world in issuing CoCos.

Table 1
Active CoCos issued by G-SIBs

A. Non-U.K. banks

G-SIBs (parent)	Active CoCos	Weight in Tier 1 capital (%)	PWD	Conversion price
Bank of China	1	2.20	Y	–
BNP Paribas	8	7.66	Y	–
Deutsche Bank	4	10.57	Y	–
Mitsubishi UFJ FG	9	8.76	Y	–
Industrial & Commercial Bank of China	1	3.01	Y	–
China Construction Bank	1	1.81	Y	–
Agricultural Bank of China	1	6.18	Y	–
Credit Suisse Group	7	17.81	Y	–
BPCE Group	0	0	–	–
Crédit Agricole Group	4	4.02	Y	–
ING Group	5	12.15	N	Unknown
Mizuho Financial Group	9	19.35	Y	–
Santander	4	17.16	Y	–
Société Générale	9	18.35	Y	–
Sumitomo Mitsui Financial Group	6	6.22	Y	–
UBS Group	13	31.53	Y	–
Unicredit Group	4	6.58	Y	–

B. U.K. banks' equity-conversion CoCos: Preset conversion price vs. market prices

Bank (parent company)	Active CoCos (equity conversion)	% as Tier 1 capital	Conversion price	Market price of bank stock (on April 20, 2020)
HSBC	13	13.59	£2.70 per share	£4.16 per share
Barclays	11	19.57	£1.65 per share	£0.91 per share
Natwest Group (previously 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

The panels summarize AT1 CoCos issued by G-SIBs from 2013 to 2019, with the G-SIBs identified by the Financial Stability Board in 2019. Equity-conversion CoCos are predominantly issued by banks in the United Kingdom, among which the 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).

common equity dropped below the preset conversion prices for most of the banks, 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 have been even lower. CoCo investors, who have to convert their bonds into equity at the preset conversion price, higher than the market price, would lose out relative to the face value of their bonds; equity holders, instead of being diluted, would be better off relative to the CoCo bond repayment.

In sum, it appears that neither PWD CoCos nor equity-conversion CoCos, under the prevailing market practice, would impose severe penalties for equity holders were the write-down or conversion to be triggered. This strongly contrasts with the envisioning that CoCos can deter share holders' risk-taking by diluting their shares upon conversion (e.g., Calomiris and Herring, 2013; Flannery, 2014, 2016).

In light of these empirical observations, we explain why dilutive CoCos are rarely, if ever, observed in practice and the implications of nondilutive designs for banks' risk-taking. Our theory builds on the basic observation that, as going-concern securities, CoCos are "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 shareholders' incentives for risk-shifting are the strongest, making it essential for CoCos to mute such perverse incentives. Indeed, if a bank's CoCos are highly dilutive, while the bank can be more resilient with 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 given two subsequent banker moral hazard actions. First, only with costly screening can a banker achieve low risk in lending and keep the bank from triggering conversion of CoCos. When the risk is not adequately managed in the first place (i.e., ex ante risk-taking), however, the bank's cash flow could fall and trigger conversion. Knowing privately whether the bank is heading toward the trigger event, the banker can take a second moral hazard action: to gamble for resurrection (i.e., ex post risk-taking), that is, to take on a risky project that would restore the cash flow and conceal the lack of screening from external investors, but at the risk of even bigger losses and bankruptcy.

CoCos, as going-concern securities, can be characterized by payoffs to their 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 is healthy and not near to the trigger event). Setting payoffs in both states involves trade-offs between discouraging ex ante versus ex post risk-taking, as described above. A nondilutive conversion in the low state preserves equity value, making nondilutive CoCos particularly powerful in preventing gambling for resurrection, even though the design violates the absolute priority rule of the bankruptcy code. Nondilutive CoCo conversions, however, make ex ante screening less valuable to the bank's shareholders, 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 come from either 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 nondilutive CoCos must offer greater payoffs to their 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.

In an agency model à la Holmstrom and Tirole (1997), we show that a trade-off can emerge in the design of CoCos between eliminating both moral hazard actions and maintaining the security's financing capacity: when a

CoCo is designed to both induce screening and avoid risk-shifting, it will create more bank value but also leave much rent to the banker and limit the financing capacity of the security. In contrast, nondilutive CoCos can generate higher pledgeable income since the design only tackles the ex post risk-shifting and thereby concedes less rent to the banker. Our theory, therefore, 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 nondilutive CoCos without triggering any risk-taking, a capital-constrained bank may have to use nondilutive CoCos to boost its financing capacity at the cost of allowing for a degree of risk-taking. In this sense, the nondilutive feature is a "necessary evil" that a constrained bank has to accept, a compromise in design that sacrifices ideal risk management for financing capacity. To make those points more obvious, we first describe them in a simplified setup with fixed investment size and in the absence of any negative externalities resulting from bank risk-taking.

To properly evaluate CoCos' role in promoting financial stability, and their position in the regulatory capital stack, we introduce a fully-fledged model where the bank can vary the size of its loan portfolio and the lack of ex ante screening leads to negative externalities, such as borrowers' losses upon loan defaults that are not accounted for by the lender. From a normative point of view, a planner, who faces the banker's moral hazard problems but has direct control over the design of the bank's financing security, would induce screening and risk-free lending only when the bank was well equity-capitalized. Otherwise, the constrained social optimum would involve allowing the banker to shirk in order to enhance the bank's financing capacity, but limiting the size of the risky loan portfolio to contain the negative externality. We show that such a constrained social optimum can be implemented by nondilutive CoCos, and the nondilutive feature is in fact necessary when the bank is low in equity. Differently from a planner, a regulator has limited control over the type of securities issued by bankers. However, we show that a regulator can partially implement the constrained social optimum by combining a capital requirement, to limit the use of debt, and a CET1 requirement, which ensures that the banker chooses the CoCo design that implements the constrained-efficient risk level.

We show that the constrained optimum cannot be implemented by other loss-absorbing regulatory capital, such as subordinated debt or nonvoting shares. Compared to subordinated debt, CoCos can be used to avoid ex post risk-shifting when a bank has higher financing needs. Relative to nonvoting shares, CoCos 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 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. Nondilutive 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 nondilutive, consistent with the prevalence of PWD CoCos and the likely low equity value upon conversion for equity-conversion CoCos. We emphasize nondilutive CoCos' effectiveness in mitigating ex post risk-shifting, and their role in boosting banks' financing capacity. We make a testable prediction that nondilutive CoCos are likely to be issued by banks that are less-than-ideally capitalized. We suggest that CoCos' designs and their implications for banks' risk-taking can only be understood and assessed in the context of banks' broader capital structure.

Finally, our paper contributes to the debate on CoCos' regulatory treatment. While many promote CoCos as securities that 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 banks' equity capitalization. Our normative analysis, in particular, reveals that the nondilutive feature is necessary to prevent gambling for resurrection when CoCos are used to implement the constrained social optimum for a highly leveraged bank. Yet, CoCos are no substitutes for banks' equity capital, despite their AT1 designation. Instead, the effectiveness of CoCos in containing risk-taking relies on banks' equity capitalization, and perhaps nondilutive CoCos remain prevalent because of the need 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 outperform subordinated debt and nonvoting shares that are also present in the regulatory capital stack.

Calomiris and Herring (2013) and Flannery (2014, 2016), among others, advocate for CoCos as securities that can automatically replenish bank capital and correct bank risk-taking incentives with their equity dilution feature. Pennacchi and Tchistyi (2019b) formally show that dilutive CoCos with a market trigger can penalize bank shareholders for excessive risk-taking, thereby promoting financial stability.[2] Further, Hilscher and Raviv (2014) argue that CoCos, when properly designed with dilution mechanisms, can curtail banks' risk-shifting incentives, even amidst financial distress.[3] Himmelberg and Tsyplakov (2020) caution that PWD CoCos may incentivize

[2] Despite the theoretical focus on market triggers by Sundaresan and Wang (2015), Pennacchi and Tchistyi (2019a), and Pennacchi and Tchistyi (2019b), actual CoCos issued by major banks generally incorporate regulatory triggers based on the CET1 ratio so that they qualify as AT1 capital.

[3] Contributions like Zeng (2014) and Yu (2016) also rationalize the hybrid and contingent convertible features of CoCos with the additional friction of information asymmetry.

shareholders to engage in value-destroying actions when a bank's financial health approaches the trigger threshold, aiming to benefit from the write-down at the CoCo investors' expense. Such theoretical support for *dilutive* CoCos' role in mitigating bank risk contrasts with the prevalence of nondilutive and PWD CoCos in the market reality.

Scholars like Admati, interviewed by Manzin (2014), question CoCos' role in promoting financial stability, considering the security to be yet another way for banks to satisfy capital regulations with a debt-like instrument instead of equity, an instrumental way for banks to boost returns on equity for their shareholders. Pennacchi (2010), Berg and Kaserer (2015), Chan and van Wijnbergen (2017), and Goncharenko, Ongena, and Rauf (2021) warn that nondilutive CoCos can create even stronger risk-shifting incentives than subordinated debt, as they may result in wealth transfers from CoCo investors to shareholders upon conversion.[4] These concerns are underscored by the prevalence of nondilutive CoCos in the market. Contrarily, we make theoretical conjectures that, depending on a bank's capitalization, strong dilution may not be necessary for CoCos to correct risk-taking incentives. Furthermore, even if nondilutive CoCos are used as a way to stretch a capital-constrained bank's balance sheet, their nondilutive feature can still contain the incentives for gambling-for-resurrection in a bank that is already undercapitalized in the conversion state.

Beyond the debate over dilution, other concerns about CoCos persist in the literature. In a global-games setting, Chan and van Wijnbergen (2014) argue that the trigger of CoCos' conversion can signal distress and aggravate creditor panics, which can also generate negative information externalities for other banks. Therefore, a security designed to reduce individual bank insolvency risks can result in funding liquidity risk and potentially financial contagion. The case study by Fiordelisi, Pennacchi, and Ricci (2020) suggests that CoCos may not function as the intended going-concern instruments, evidenced by their conversion only after a bank's collapse. De Spiegeleer and Schoutens (2013) note that CoCo investors might hedge the risk of nondilutive conversion by short-selling the issuing bank's equity, which could depress the equity price and makes CoCos' conversion self-fulfilling.

The theory paper most related to ours is that of Martynova and Perotti (2018), who theorize the dominance of PWD CoCos without fully considering a bank's capital structure. They conclude that PWD CoCos with full and permanent write-downs are optimal, whereas we propose a more moderate view: while both dilutive and nondilutive CoCos can theoretically keep the bank's risk low, the latter requires sufficient initial equity capitalization. In scenarios in which equity is constrained, nondilutive CoCos emerge as a

[4] Goncharenko (2022) adds to this concern, arguing that the write-up feature in temporary write-down (TWD) CoCos could discourage shareholders from taking efficient actions like capitalization and containing risk-taking.

"necessary evil" for a capital-constrained bank, through which it boosts its financing capacity at the cost of reducing bank value, representing a constrained optimum in our model.[5]

Empirically, Avdjiev et al. (2020) find a decline in banks' credit default swap spreads following CoCo issuance, suggesting a beneficial effect from the securities' loss-absorbing features or the mitigation of risk-taking behavior. Supporting this, Fiordelisi, Pennacchi, and Ricci (2020) observe that the issuance of equity-conversion CoCos correlates with reduced bank risks, such as equity return volatility. Our theoretical prediction that nondilutive CoCos can reduce risk-taking by undercapitalized banks aligns with Vallée (2019). The author documents that, during the 2007–2008 financial crisis, European banks reduced their risks, via the Liability Management Exercises, by refusing to call subordinated debt at par on the first call date and simultaneously launching highly discounted tender offers on the same debt. While these measures hurt the value of subordinated debt, they allowed the banks to book consequent capital gains. The mechanism can be seen as a precursor of CoCos with nondilutive conversion/write-down.

1. CoCo Bonds in a Simplified 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. All agents are risk neutral, and the risk-free rate is normalized to zero.

The bank's baseline capital structure comprises deposits D and paid-in equity E provided by the banker. We assume that the deposits are fully insured and the deposit insurance premium has already been paid so that the retail deposits are risk-free.[6]

In the simplified setup of this section, the banker maximizes her expected payoff at $t = 0$ by investing in a long-term loan portfolio, which requires 1 unit of initial capital input and matures at $t = 2$. We assume that $D + E < 1$, to avoid the trivial case in which no additional external financing is needed. To finance the project, the banker issues a security to outside investors, who will bid competitively and only break even from purchasing the security. P denotes the price of such a security. 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 nonvoting shares.

[5] Our model also suggests that CoCos designed with full and permanent write-downs do not maximize financing capacity due to the reduced payoffs to investors. This aligns with the market presence of CoCos featuring only partial and temporary write-down mechanisms (e.g., temporary suspension of coupons).

[6] Alternatively, we can assume D to be legacy debt (issued and priced before $t = 0$) with no change in our results. Introducing D allows us to define bankruptcy and CoCos as going-concern securities. When D is interpreted as insured deposits, it also rationalizes capital regulations, as shown in Section 2.4.

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 screening will make the loan portfolio risk-free and generate a sure return $R > 1$. The screening effort is noncontractible, though. If the banker shirks, she gains an immediate private benefit, G, but leaves the bank exposed to the risk of loan defaults. The effect of loan defaults 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, that is, $R' > D$, screening is socially efficient and the expected loss on loans from no screening exceeds the banker's private benefit:

$$p(R-R') > G. \tag{1}$$

For a risky bank to be financed on the equilibrium path, we also assume that the loan portfolio has a positive expected cash flow, even in the absence of the banker's screening:

$$(1-p)R + pR' > 1. \tag{2}$$

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 follow-on 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.[7] The project has a negative net present value (NPV):

$$(1-q)R - R' < 0. \tag{3}$$

The upside of the gamble restores the cash flow to R and conceals the fact that the banker did not screen the loans properly. The loss on the downside, however, will make the bank default on its retail deposits, in which case the deposit insurance scheme has to pay D to the depositors. In effect, the gamble shifts the risk to the deposit insurance. While the outside investors can observe the terminal cash flow of the bank, they cannot observe the banker's risk-shifting action at $t = 1$.

We assume that 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:

$$(1-pq)R - 1 + pqD > 0, \tag{4}$$

so that a bank with a positive probability of default may be financed in the first place. Therefore, securities to prevent such risk-taking are desperately needed.

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

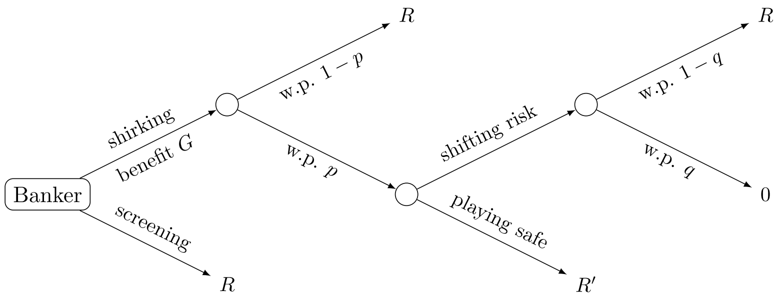


Figure 1
The banker's moral hazard actions and the resultant cash flows

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 the gamble, either $2R-R'$ or $R-R'$, will perfectly reveal the banker's risk-shifting. Hence, a regulator can detect and deter it by imposing ex post 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, because the return R resulting from a successful gamble cannot be differentiated from the safe return generated from screening. Figure 1 shows the banker's actions and the resultant cash flows.

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. $\mathcal{E}_i$ denotes the NPV that accrues to the banker for a risk level i.

Level 0: If the banker screens the loans and does not shift risks, her net value is

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

Level 1: If the banker shirks from screening but does not shift risks, her net value is

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

Level 2: If the banker both shirks and shifts risk, her net value is

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

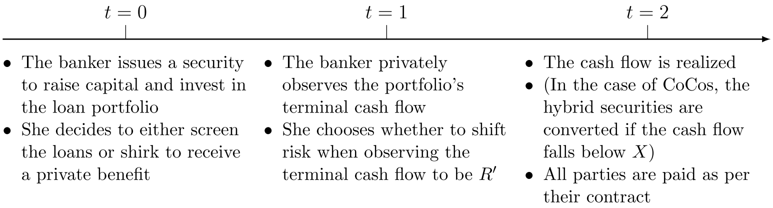


Figure 2
Timeline of the model

Moving from Levels 0 to 1, the banker destroys value due to the lack of screening but gains the private benefit from shirking. Moving from Levels 1 to 2, the banker destroys additional value with inefficient risk-taking but gains pqD from shifting the risk to the deposit insurance fund. From conditions (1) and (2), we have $0<\mathcal{E}_1<\mathcal{E}_0$. 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

$$R-D<\frac{R'-D}{1-q}. \tag{5}$$

Because both moral hazard actions are value-destroying ($\mathcal{E}_2<\mathcal{E}_1<\mathcal{E}_0$), the banker will try to minimize the risk provided that she can still raise sufficient external financing to invest in the portfolio.[8] Figure 2 summarizes the timeline of our model.

To model CoCos as going-concern securities, we assume their conversion trigger, X, is such that $X>R'>D$.[9] The CoCo pays a face value of F as a bond if the bank's cash flow exceeds X. Otherwise, the CoCo is converted to a fraction $\lambda\in[0,1]$ of equity, while the banker, as the existing shareholder, receives the residual fraction.

Given the conversion trigger, a CoCo bond's payoff is fully characterized by the two parameters, F and λ, to be chosen from the set $\mathcal{C}=[0,R-D]\times[0,1]$, where $F\leq R-D$ is a consequence of the limited liability of equity. Note that there are only two states in which a CoCo can generate a positive payoff: R' (the conversion state) and R (the nonconversion state).[10] While λ pins down the CoCo's payoff in the R' state, F pins down the CoCo's payoff in the R state.

8 This feature is generic to models with settings like those in Holmstrom and Tirole (1997). For a detailed exposition of the banker's problem, see Internet Appendix A.

9 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 in which CoCos are only converted when the bank generates a zero payoff and CoCo investors receive nothing in conversion. Noticeably, X is not necessarily a CET1 trigger and can be a point of nonviability at which the regulator steps in.

10 Obviously, in the state in which the cash flow is 0, CoCo investors will have to receive a zero payoff since the other claim holders are all protected by limited liability.

Table 2
Payoffs to all parties (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	$-D$

A CoCo bond is dilutive for shareholders if CoCo investors receive more than the bond's face value upon CoCo conversion, that is, $\lambda(R'-D) \geq F$. Otherwise, the CoCo bond is nondilutive for shareholders.[11] 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. Nondilutive CoCos are unique securities as they are junior to equity. Indeed, CoCo holders lose value upon conversion (as compared to the principal of the bonds they surrender), whereas equity holders are better off relative to the situation where they need to make CoCo bond repayments. Table 2 summarizes different parties' payoffs in all contingencies.

The equilibrium design of the CoCo bond depends on (a) the moral hazard actions (if any) that it entails and the corresponding payoff to the banker as the existing shareholder and (b) whether the CoCo bond can raise enough to finance the loan portfolio. We will analyze these two aspects in the next two sections.

1.1 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 $\Pi_0^C(F, \lambda) = R-D-F$ if she screens at $t=0$ and does not shift risk at $t=1$. If she, instead, shirks at $t=0$, but not to gamble at $t=1$—even if the outcome is R'—her expected payoff will be $\Pi_1^C(F, \lambda) = p(1-\lambda)(R'-D) + (1-p)(R-D-F) + G$. Finally, if the banker both shirks and shifts risk, her 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. 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 the return R with two strategies that cannot be told apart by the outsiders: either by screening the loan portfolio, or by shirking and being lucky when shifting risk. As a result, assigning the banker a high payoff in state R generates incentives both for screening and for

[11] This notion is widely adopted in the literature. For examples, see Calomiris and Herring (2013) and Himmelberg and Tsyplakov (2020). Calomiris and Herring (2013) define dilutive CoCos 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."

risk-shifting. Similarly, a high payoff in state R' discourages risk-shifting, but also reduces the incentive to screen loans.[12]

Design 0. We first consider CoCo designs that induce no moral hazard action from the banker. Such designs must simultaneously satisfy $\Pi_0^C \geq \Pi_1^C$ and $\Pi_0^C \geq \Pi_2^C$. The first incentive constraint is equivalent to $\lambda \geq \frac{F-(R-R')+G/p}{R'-D} \equiv \lambda_0(F)$, which states that 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 $F \leq (R-D) - \frac{G}{p}$. The second incentive constraint, $\Pi_0^C \geq \Pi_2^C$, is equivalent to $F \leq (R-D) - \frac{G}{pq} \equiv F_0$. For such a design to be feasible, F_0 must be positive, that is, $\frac{G}{pq} \leq R-D$, which is implied by conditions (1) and (5). Both incentive constraints set upper bounds on the face value of CoCo bonds F, and the latter is more restrictive than the former for $q<1$.

The intuition is that 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 by a low face value of the CoCo bond, as reflected by condition $F<F_0$. The latter can be achieved by 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 is avoided as the R' state will not occur on the equilibrium path. The blue area in Figure 3 depicts the subset of $\mathcal{C}$ in which 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 $F \geq (R-R') - \frac{G}{p} \equiv F_1$. On the other hand, the banker will not shift risk if $\Pi_1^C \geq \Pi_2^C$, which implies $\lambda \leq \frac{(1-q)F-(R-R')+q(R-D)}{R'-D} \equiv \lambda_1(F)$ and sets an upper bound on λ. Condition (5) 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 $F \geq F_1$. We illustrate the relevant subset of $\mathcal{C}$ as the red area in Figure 3.

Intuitively, 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 loans, which is allowed under this case, such a design also reduces the banker's upside from (and incentive for) shifting risks.

[12] 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, the CoCo, should be designed to tackle the frictions.

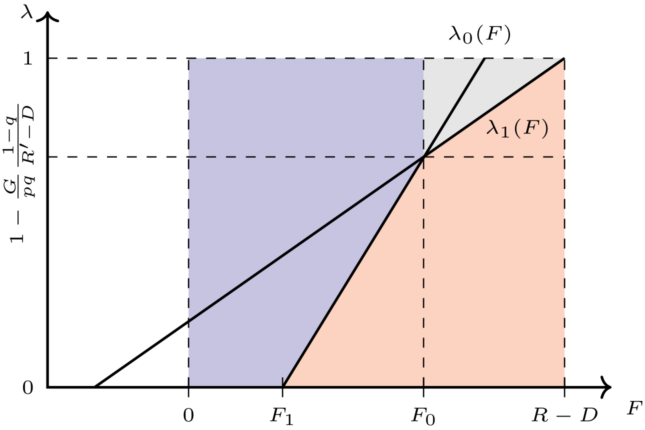


Figure 3
CoCo designs and bank risks
A CoCo contract is characterized by its face value (F, horizontal axis) and CoCo investors' share after conversion (λ, vertical axis). The blue area represents CoCos that result in no moral hazard (Design 0); the red area represents CoCos that allow for shirking but avoid risk-shifting (Design 1); and the gray area represents CoCos that lead to both moral hazard actions.

Design 2. The banker will have incentives to both shirk and shift risk if the constraints $\Pi_2^C \geq \Pi_0^C$ and $\Pi_2^C \geq \Pi_1^C$ hold simultaneously. The conditions supplement those required for Designs 0 and 1, and the relevant subset of $\mathcal{C}$ is depicted by the gray area in Figure 3.

We summarize these results regarding CoCo bond designs in Lemma 1.

Lemma 1. If $F \leq F_0$ and $\lambda \geq \max\{\lambda_0(F), 0\}$, the CoCo prevents both moral hazard actions of the bankers and has price $P_0^C(F,\lambda) = F$.

If $F \geq F_1$ and $\lambda \leq \min\{\lambda_0(F), \lambda_1(F)\}$, the CoCo allows the banker to shirk but prevents risk-shifting and has price $P_1^C(F,\lambda) = (1-p)F + p(R'-D)\lambda$.

A CoCo with $F \geq F_0$ and $\lambda \geq \lambda_1(F)$ allows for both shirking and risk-shifting and has price $P_2^C(F,\lambda) = (1-pq)F$.

1.2 CoCos' financing capacity and the equilibrium design

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

From the banker's perspective, a CoCo contract has two features that matter: the risk level that it entails (that is, the number of moral hazard actions that it will induce the banker to take), and the amount of capital that it allows the bank to raise. As noted, the banker prefers a CoCo design that leads to the lowest risk level, provided that the CoCo can raise enough capital to finance the loan portfolio.

Lemma 1 has established that, for each risk level i associated with corresponding moral hazard actions, there is a CoCo price $P_i^C(F,\lambda)$ that varies with the design parameters. Since a risk level can be implemented using a continuum of CoCo contracts, CoCos that lead to the same risk level can carry different prices. Because the banker only cares whether a loan portfolio of a certain risk level can be financed, 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 produce a particular risk level, or the pledgeable income of such securities, that 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 the three designs, the following proposition shows that Design 1 can have the highest financing capacity (proof in Internet Appendix (IA) B.1).

Proposition 1. CoCos of Design 0 allow the banker to raise at most $R-D-\frac{G}{pq}$; and 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

$$\frac{G}{pq} > p(R-R'). \tag{6}$$

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 lowers the rent that has to be kept for the banker, making the amount available to CoCo investors bigger. As a result, when the shirking problem is severe, moving from Design 0 to Design 1 can increase CoCos' pledgeable income. In what follows, we will assume that the gain from shirking is sufficiently high that (a) Design 1 has a greater financing capacity than Design 0 (i.e., condition (6) holds) and (b) a bank with no paid-in equity cannot finance the investment with Design 0 (i.e., $R-D-\frac{G}{pq}<1-D$ or $\frac{G}{pq}>R-1$).[13] In fact, one can show that the inequality (6) is implied by inequality $\frac{G}{pq}>R-1$ which in turn is implied by condition (2).

Assumption 1. In what follows, we will assume that the moral hazard problems for the banker are sufficiently strong, that is, $\frac{G}{pq}>R-1$.

CoCos of Design 1 always have a greater financing capacity than those of Design 2. Intuitively, there is no conflict of interest between the banker and CoCo investors in shifting risks to insured deposits, so that CoCo investors do

[13] If either of these two assumptions is not true, Design 1 is dominated by Design 0—in terms of both the value of the 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.

not need to pay any agency rent to the banker to discourage risk shifting. Therefore, compared to Design 1, Design 2 provides no greater financing capacity to the banker, because it only reduces the total amount of cash flow available.

We now analyze the optimal design of CoCo bonds in relation to the bank's equity capitalization. Design 0 and Design 1 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 security's pledgeable income; the latter, while generating 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. Hence, the former is 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 (proof in IA B.2).

Proposition 2. While a bank with $E < \frac{G}{pq} - (R-1)$ can only finance its loan portfolio with CoCos of Design 1 that avoid risk shifting at the cost of allowing for shirking, a bank with $E \geq \frac{G}{pq} - (R-1)$ will issue CoCos of Design 0 to avoid both moral hazard actions. The banker's net value is

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

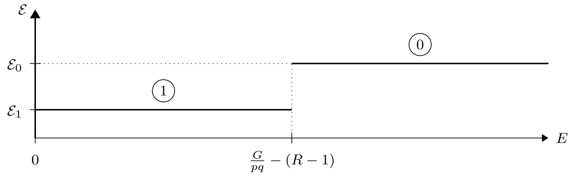
1.3 CoCo dilutiveness, financing capacity, and bank risks

We have shown that Design 1 CoCos provide an enhanced financing capacity and will be chosen by equity-constrained banks; Proposition 3 now establishes that all such CoCos are in fact nondilutive for shareholders: they do not transfer wealth from equity holders to CoCo investors upon conversion (proof in IA B.3).

Proposition 3. All CoCos of Design 1 are nondilutive, that is, $\lambda < \frac{F}{R' - D}$, whereas dilutive CoCos do not maximize the bank's financing capacity.

Propositions 2 and 3 jointly show that nondilutive CoCos can be seen as a "necessary evil": the nondilutive conversion is a design that constrained banks (those with $E < \frac{G}{pq} - (R-1)$) have to accept to make financing feasible, even though the banker would prefer to issue CoCos of Design 0 for a higher NPV if her bank 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.



The figure plots the banker's net value, $\mathcal{E}$, resulting from the choice of CoCo designs against the bank's paid-in equity, E. (0) is associated with CoCos that lead to no moral hazard, (1) with CoCos that lead to shirking.

Figure 4
The bank's value and the banker's financial constraint

First, CoCos need not be dilutive to promote financial stability. The hatched area in Figure 5 represents the CoCo designs that are dilutive for shareholders in the case $\frac{G}{pq} \leq R - R'$. Indeed, nondilutive CoCos can implement bank safety (if it can be financed) as shown by the blue region that is not hatched. However, CoCos can be dilutive in designs associated with high risks. Indeed, Figure 6, for the case in which the agency cost is high, $\frac{G}{pq} > (R - R')$, shows that dilutive CoCos can be found in a subset (the red triangle) of Design 2. Thus, depending on the parameters, dilutive conversion can be neither a necessary nor sufficient condition for implementing safety for a bank. The existence of the green-bordered area shows that dilutive conversion is not a necessary condition for bank safety, whereas, when $\frac{G}{pq} > (R - R')$, the existence of the red-bordered area shows that dilutive conversion is not a sufficient condition for implementing bank safety. We summarize these results in the following corollary (proof in IA B.4).

Corollary 1. Depending on the agency cost G, dilutive CoCos are not necessarily associated with only risk-free designs: if $\frac{G}{pq} \leq R - R'$, all dilutive CoCos are within Design 0, but Design 0 CoCos also can be nondilutive (Figure 5); if $\frac{G}{pq} > R - R'$, in addition to those in Design 0, dilutive CoCos can also fall within Design 2 (Figure 6).

The impact of dilutive CoCos on bank risk depends on a bank's equity capitalization. When the bank is well capitalized, shirking is not attractive, and a safe bank can be produced with either dilutive or nondilutive CoCos.[14] However, forcing a dilutive design on the CoCos issued by a capital-constrained bank can lead to higher risk. If G is sufficiently high and there are major agency frictions in raising external financing, a constrained banker issuing dilutive CoCos will engage in both shirking and risk-shifting. The next proposition summarizes the results (proof in IA B.5).

[14] In fact, if $E > 1 - D - F_1$, a bank 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 CoCos' dilutiveness to keep the bank risk-free.

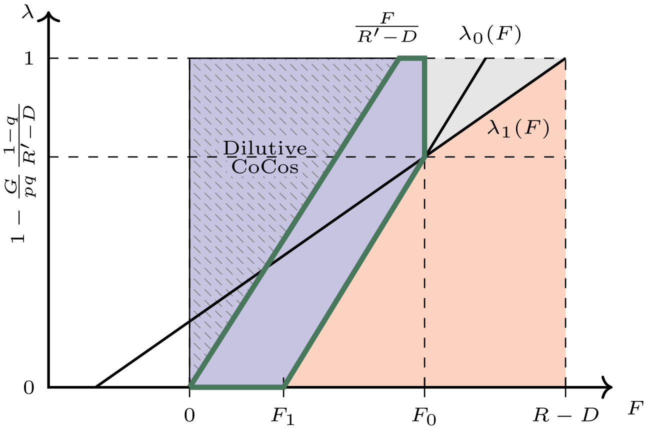


Figure 5
Bank risk and corresponding CoCo designs (illustration with $\frac{G}{pq} \leq R - R'$)
Refer also to the legend to Figure 3. The hatched area represents the CoCo contracts that feature dilutive conversion (i.e., $\lambda(R'-D) \geq F$). The green-bordered area represents CoCos with nondilutive conversion that can be used to implement bank safety, showing that dilutive conversion is not a necessary condition for bank safety.

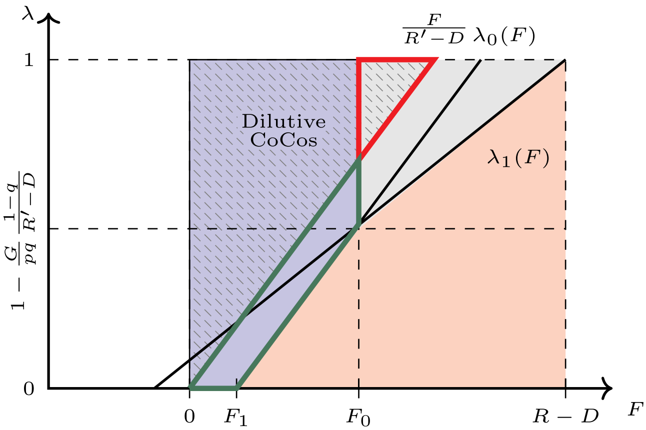


Figure 6
Bank risk and corresponding CoCo designs (illustration with $\frac{G}{pq} > R - R'$)
In addition to the legends to Figures 3 and 5, the red-bordered area represents CoCos with dilutive conversion, which nevertheless result in both banker shirking and risk-shifting, showing that dilutive conversion is not a sufficient condition for implementing bank safety.

Proposition 4. Dilutive CoCos' impact on risks depends on a bank's equity capital.

A well-capitalized bank with $E \geq \frac{G}{pq} - (R-1)$ can implement the safe investment using either dilutive or nondilutive CoCos with face value $F = F_0$.

If the agency cost is high, $\frac{G}{pq} > (R-R') + pq(R'-D)$, a less-capitalized bank with $E \in [pq(R'-D)-(R'-1), \frac{G}{pq}-(R-1)[$ issuing only dilutive CoCos will opt for Design 2.

With a high agency cost, a bank with low equity capitalization, $E < pq(R'-D)-(R'-1)$, cannot be financed.

Proposition 4 shows that CoCos are no substitute for bank equity. Rather, CoCos' designs and their impacts on bank risks crucially depend on a bank's equity capitalization. Depending on banks' capitalization, the prevalence of nondilutive CoCos has two possible interpretations. If bank capital is sufficient, nondilutive designs should not raise any concerns per se, because they can deliver the lowest risk. An alternative and less favorable interpretation is that capital-constrained banks use nondilutive CoCos to stretch the size of their balance sheets but only at the cost of allowing for a degree of moral hazard (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 for 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 will be useful to examine 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 remarks are in order. First, PWD CoCos can be found both within Design 0 and Design 1, which reaffirms our observation that nondilutive CoCos can still result in low risk when the bank is sufficiently capitalized. Indeed, a bank with $E > \frac{G}{p} + (R'-D) - (R-1)$ can finance itself with risk-free PWD CoCos. Second, while PWD CoCos with full and permanent write-down features do not maximize the financing capacity of CoCos in our setting, they may still allow for a greater financing capacity than dilutive CoCos and be preferred by an equity-constrained bank. More precisely, a Design 1 PWD CoCo generates a higher financing capacity than equity-conversion CoCos of Design 0 if and only if $\frac{G}{pq} > p(R-D)$, in which case constrained banks will prefer the Design 1 PWD CoCo. The proof of these results is in IA B.6.

2. A General Model of CoCos and Capital Regulation

Building on the simplified analysis, we now present a fully-fledged model to gain a normative perspective on the efficacy of CoCos as a financing instrument and evaluate their role in capital regulations. We do so by (1) relaxing the assumption of the fixed investment size and (2) introducing a negative externality caused by the lack of banker screening. The model shows that not only can an equity-constrained bank find it privately optimal to issue nondilutive CoCos to expand its investment size but also that nondilutive CoCos can be used to achieve a social optimum in the presence of the two moral hazard problems.

For the first main difference from the simplified model, we now allow the size of the bank's loan portfolio to vary, and let the banker decide on the size of the investment I at $t = 0$ to maximize her expected payoff. This allows for the possibility of opting for a smaller investment size without resorting to CoCos that maximize the pledgeable income, and also to take a $t = 0$ payout to further increase the leverage of the bank. For simplicity, the investment technology is assumed to feature constant returns to scale up to a size of $\bar{I} < \infty$, with the rate of return on investment as follows. For an investment of size $I \leq \bar{I}$, the $t = 2$ rate of return depends on the banker's strategy, in the same way as it does in the fixed investment size model: the rate equals $R > 1$ if the banker screens the loan portfolio, but drops to $R' < R$ with probability p if the banker shirks, in which case the banker obtains an immediate private benefit G per unit of investment. If, at $t = 1$, the banker anticipates a terminal rate R', she can engage in risk-shifting, which restores the rate of return of R with probability $1-q$ but wipes out the investment with probability q. For simplicity, we assume that, when the investment I exceeds $\bar{I}$, the net return for any additional investment becomes negative, so it will never be efficient to set the size of the investment to $I > \bar{I}$.[15]

To finance the loan portfolio, besides paid-in equity, E, the banker has access to retail deposits in a fixed supply D.[16] While the amounts of paid-in equity and insured deposits are fixed, when utilizing internal capital (from either paid-in equity or deposits) yields a positive net return, the banker can issue a new security that generates proceeds P, to increase the size of the investment. The banker can also pay herself dividends at $t = 0$ if internal capital is higher than the optimal investment size.

$e_0 \equiv R - 1$ denotes the net private return on investment to the banker if she both screens the loan portfolio and avoids risk-shifting, by $e_1 \equiv pR' + (1-p)R - 1 + G$ the return if the banker avoids risk-shifting but does not screen the loan portfolio, and by $e_2 \equiv (1-pq)(R-1) + G$ the net private return if the banker engages in both moral hazard actions, including the transfer from deposit insurance.[17] We assume the banker's net private return from engaging in both moral hazard actions, absent the deposit insurance subsidy, $e_2' \equiv (1-pq)R - 1 + G$, to be negative, so that the net return for

[15] This assumption on the investment technology *de facto* assumes decreasing returns to scale but with discontinuity at the investment size $I = \bar{I}$.

[16] The fixed amount of paid-in equity captures high costs of equity issuance due to market frictions, such as asymmetric information, whereas the fixed supply of retail deposits is intended to capture the fact that enlarging the retail customer base usually involves opening new branches, which is costly at least in the short run.

[17] As proven in Lemma 3, if the banker chooses to shift risk, the investment size is D. Here, we are defining the rate of return on investment, $\mathcal{E}_2 = e_2$ if $D = 1$.

the banker, e_2, becomes positive only when such a subsidy is included. Under Assumption 1, we also have $e_0 < e_2$, which states that, when the bank is highly leveraged and only finances its investment with insured deposits, engaging in both moral hazard actions generates the highest rate of return to the banker. In other words, the motive for shifting risk to the deposit insurance fund is substantial. However, $e_0 < e_2$ does not imply that the banker always chooses the highest risk level, since a lower risk level can lead to a larger investment size. In summary, we maintain the following parametric assumptions:

$$e_2' < 0 < e_1 < e_0 < e_2. \tag{7}$$

The second main difference from the simplified model is that the lack of banker screening is assumed to generate a negative externality on the broader economy, which allows us to differentiate the social value from the private value of investment and gain a normative perspective on CoCos. We assume that the social cost of not screening is φI^2, $\varphi \geq 0$, for a loan portfolio of size I. The social cost can be microfounded by considering the loss of jobs, destruction of employees' firm-specific human capital, or disruption in the provision of essential goods and services. Also, when a loan is defaulted upon, there is a loss in the borrowing firm's equity value in addition to the loss incurred by the lender. The negative externality when the banker shirks creates a wedge between the social and private values of the bank's loan portfolio.[18] We assume that, if the banker shirks but does not engage in risk-shifting, the net value is positive from a social perspective:[19]

$$e_1 I - \varphi I^2 > 0. \tag{8}$$

In a frictionless world in which the banker's actions are contractible, the banker will carry out screening and will not engage in risk-shifting. In such a world, the form of the financing instrument becomes irrelevant, and the banker faces no constraints in raising external financing and maximizes the efficient investment size by reaching $I = \bar{I}$. A risk-free first-best investment of size $\bar{I}$ leads to a social surplus $V_0^S(\bar{I}) = e_0 \bar{I}$.

2.1 Banker's private decision

We now analyze the banker's private decision, in particular, the endogenous choice of risk and the sizes of investment associated with different levels of risk.

[18] The quadratic form of the social cost is only assumed for convenience. The result would remain qualitatively the same with any convex social cost function. We also assume that the social costs are incurred at the time shirking occurs, before the negative outcome of such an action is realized. An alternative assumption that the social cost is incurred after the realization of the negative economic state (R' would just amount to a different parametrization, while the results would remain the same.

[19] Because $e_1 - \varphi I$ decreases in I, a sufficient condition for (8) to hold is $e_1 - \varphi \bar{I} > 0$.

We start by analyzing the bank's feasible investment size for each *given* risk level. As usual, $i = 0, 1, 2$ indexes the risk level, or equivalently the number of moral hazard actions taken by the banker (respectively, no moral hazard, shirking only, and shirking plus gambling for resurrection). To raise additional financing, the banker can issue a security that pays $r(R)$, $r(R')$, or 0 to the outside investors if the loan portfolio returns R, R', or 0, respectively. The banker's expected payoff is

$$\Pi_0 = RI - D - r(R)$$

if she screens the portfolio and does not engage in risk-shifting,

$$\Pi_1 = (1-p)(RI - D - r(R)) + p(R'I - D - r(R')) + GI$$

if she does not screen the portfolio but avoids risk-shifting, and

$$\Pi_2 = (1-pq)(RI - D - r(R)) + GI$$

if she both shirks and engages in risk-shifting. The following result simplifies our analysis (proof in IA B.7).

Lemma 2. The limited liability constraint will never bind when the bank's cash flow is R or R' and therefore the banker's equity will be strictly positive. In particular, the bank does not default in the R' state and shall remain a going concern.

We now study the financing capacity of the security issued by the banker. As in Section 1, we will dub a security as having a Design i when it induces a risk level i. Consider Design 0 first. The banker takes no moral hazard action if and only if $\Pi_0 \geq \Pi_1$ and $\Pi_0 \geq \Pi_2$. The two incentive constraints jointly suggest that a strictly positive amount of equity ($E > 0$) is necessary for risk-free investment, and the maximum investment size I_0^P will be given by an equity multiplier:

$$I_0^P = \frac{E}{G/(pq) - e_0}.$$

To focus on cases where the banker's moral hazard leads to allocations different from the first-best, we assume that the bank's paid-in equity is sufficiently small and/or moral hazard problem sufficiently severe that $I_0^P < \bar{I}$.

Assumption 2. For the remainder of the analysis, we assume $I_0^P < \bar{I}$.

If the security is designed to achieve risk level 1 instead, the banker's two incentive constraints $\Pi_1 \geq \Pi_0$ and $\Pi_1 \geq \Pi_2$ must be satisfied, so she will not screen the loan portfolio but will still avoid risk-shifting. These constraints set two upper limits on $r(R')$, both of which monotonically increase in $r(R)$. For the maximum $r(R) = RI - D$, it can be shown that the constraint $\Pi_1 \geq \Pi_0$ is slack as compared to the constraint $\Pi_1 \geq \Pi_2$, which suggests a maximum payoff to the financiers in the R' state of $r(R') = R'I - D$. It follows that the proceeds from issuing securities will exceed the financing need:

$$P = (1-p)r(R) + pr(R') = (1-p)(RI-D) + p(R'I-D)$$
$$= [(1-p)R + pR']I - D > I - D,$$

In other words, a loan portfolio of Risk Level 1 is self-financing with no need for using the banker's equity. The banker's optimal private choice is to push the size of the investment to the maximum, that is $I_1^P = \overline{I}$.

Therefore, like in the simplified model, a trade-off arises in the banker's optimization problem between obtaining a large investment size and a high marginal return on investment. In particular, when the issued security induces screening efforts, the banker benefits from a high portfolio return, e_0, but the investment size is constrained by limited equity capitalization, which ultimately reduces the bank's profitability. Therefore, a banker may be better off if she increases the investment size at the cost of letting the net return on the asset drop to e_1, by issuing a security that allows shirking but prevents risk-shifting.

Finally, when engaging in risk-shifting, the banker will set the investment size equal to D, which is achieved by paying out equity as a dividend at $t = 0$ and avoiding external financing. Intuitively, even though lending with two moral hazard actions is value-destroying, the banker benefits from the wealth transfer from the deposit insurance at default. Any investment higher than D reduces equity value because such a transfer is proportional to the deposits and not to the size of the investment. The banker will not choose an investment size strictly smaller than D, either since investing D maximizes the benefit of the deposit insurance subsidy, and paying an additional dividend using D would give her a lower payoff than if the same amount had remained invested in the bank.

We formally prove these results in IA B.8 and summarize them in the following lemma.

Lemma 3. A risk-free bank, in which the banker takes no moral hazard action, has net return e_0 but the investment is bounded by I_0^P. If the banker shirks but avoids risk-shifting, the net rate of return reduces to e_1, but the bank's loan portfolio becomes self-financing and so the optimal size is $\overline{I}$. If both moral hazard actions are taken, the optimal investment size is D, and the net rate of return is e_2.

While the first-best allocation entails a risk-free loan portfolio of size $\overline{I}$, such an efficient investment level can be infeasible in the presence of moral hazard problems. When the investment size and risk are jointly determined, the private optimal choice depends on the bank's existing capital structure, as summarized in the following proposition (proof in IA B.9).

Proposition 5. Define $\widehat{D}^P \equiv \max\{\frac{e_0}{e_2} I_0^P, \frac{e_1}{e_2}\bar{I}\}$ and $\widehat{E}^P \equiv \frac{e_1}{e_0}\left(\frac{G}{pq} - e_0\right)\bar{I}$.

A bank endowed with insured deposits $D > \widehat{D}^P$ will engage in both moral hazard actions (Risk Level 2) to shift risk to the deposit insurance fund, and will invest only D in the risky loan portfolio while paying out E as a dividend at $t = 0$.

A less levered, although still equity-constrained, bank with $D \leq \widehat{D}^P$ and $E < \widehat{E}^P$ will not screen the loan portfolio and will not shift risks (Risk Level 1). The resultant risky loan portfolio is self-financing, and the bank's investment size is $\bar{I}$.

A bank with $D \leq \widehat{D}^P$ and $E \geq \widehat{E}^P$ will screen the loan portfolio (Risk Level 0) and finance an investment portfolio of size I_0^P.

Intuitively, when choosing between Risk Level 2 and the other lower risk levels, a highly leveraged bank financed by a large amount of insured deposits ($D > \widehat{D}^P$) will find ex post risk-shifting particularly attractive. A less leveraged bank that enjoys a lower deposit insurance subsidy, on the other hand, will give up the subsidy and reduce the risk level to grow the investment size beyond D. When choosing between Risk Levels 0 and 1, a less leveraged yet equity-constrained bank (i.e., $D \leq \widehat{D}^P$ and $E < \widehat{E}^P$) will choose to sustain a large investment size at the cost of a reduced return on investment. To push the investment to $\bar{I}$, the bank designs and issues securities that make the loan portfolio self-financing at Risk Level 1. Nondilutive CoCos achieve such a goal, since they give a limited agency rent to the banker and create more pledgeable income by only partially dealing with the agency problem.[20]

2.2 Constrained social optimum

We now analyze the constrained social optimum, which obtains if the social planner endeavors to maximize the social value of investment while facing the banker's moral hazard problem. To start with, note that the net social value is negative if the banker takes both moral hazard actions. Indeed, since the deposit insurance payment is only a transfer between the bank and the deposit insurer, $e_2' I - \varphi I^2 < 0$ is a consequence of inequality (7). Therefore, the social planner, by restricting the design of issued securities, will set a bank's capital structure such that the banker never chooses Risk Level 2.

Given the banker's moral hazard problem, the social planner will face a trade-off between inducing lower risk-taking from the banker (and therefore boosting the return on investment) and maintaining a large investment size.

[20] As in the simplified model in Section 1, nondilutive CoCos are a "necessary evil," in that they allow for shirking but achieve the financing goal. In contrast, a better-capitalized bank (i.e., $D \leq \widehat{D}^P$ and $E \geq \widehat{E}^P$) will not engage in either of the moral hazard actions but will be constrained by a limited investment size of I_0^P.

When the social planner chooses Risk Level 1, the socially optimal investment will also differ from the banker's optimal private investment, due to the negative externality from the lack of screening. The following proposition presents the constrained social optimum (proof in IA B.10).

Proposition 6. In the presence of the banker's agency problems, a social planner can achieve the first-best allocation (Risk Level 0 and investment $I_0^S = I_0^P$) if and only if the banker's capital endowment exceeds a critical level

$$\widehat{E}^S \equiv \frac{1}{4\varphi}\frac{e_1^2}{e_0}\left(\frac{G}{pq} - e_0\right).$$

When the bank is equity-constrained, with $E < \widehat{E}^S$, the constrained social optimum is to shirk but avoid risk-shifting (Risk Level 1). The constrained socially optimal investment is $I_1^S = e_1/(2\varphi)$, from which the net optimal social value is $V_1^S(I_1^S) = e_1^2/(4\varphi)$. The social planner will never choose Risk Level 2 since it would result in a negative social value.

In what follows, we assume φ to be high enough that $I_1^S < \bar{I}$. In other words, under Risk Level 1, private decisions will result in overinvestment.

Assumption 3. We assume $I_1^S < \bar{I}$ for the remainder of the analysis.

Proposition 6 highlights that screening is socially optimal only if the bank is well-capitalized. Although Risk Level 0 delivers a high return, undercapitalized banks are constrained by the feasibility conditions. As a consequence, unconstrained investment size at Risk Level 1 creates a higher social value in those banks. Indeed, the investment is bigger with Risk Level 1 than with Risk Level 0 when the bank is capital-constrained with $E \leq \widehat{E}^S$. To see this, note that, for $E = \widehat{E}^S$, the lowest level of endowment for which Risk Level 0 is possible, the inequality $I_0^S < I_1^S$ or, explicitly,

$$\frac{E}{G/(pq) - e_0} \leq \frac{e_1}{2\varphi},$$

is equivalent to $e_1 < 2e_2$, which follows from conditions (1) and (2).

The banker's problem in the absence of any regulation is to maximize her private value, which does not take negative externalities into account. That means both shirking and risk-shifting are less costly to the banker then they are to the social planner. Because of this, the banker's private choice involves overinvestment and inefficient risk-taking, as shown in the next corollary.

Corollary 2. The equity thresholds $\widehat{E}^S$ and $\widehat{E}^P$ are such that $\widehat{E}^S < \widehat{E}^P$, and the banker's private choice deviates from the constrained social optimum in three aspects:

1. *if* $E \in [\widehat{E}^S, \widehat{E}^P[$*, the banker will choose Risk Level 1 rather than Risk Level 0 as in the constrained social optimum;*
2. *at Risk Level 1, the banker overinvests in risky loan portfolios by setting* $\bar{I}$ *rather than* $I_1^S < \bar{I}$*;*
3. *a highly leveraged bank with insured deposits (i.e.,* $D > \widehat{D}^P$*) will choose Risk Level 2 and invest D, whereas the social planner will never choose such a risk level.*

The inequality $\widehat{E}^S < \widehat{E}^P$ follows from the fact that $\widehat{E}^P / \widehat{E}^S = 4\varphi\bar{I}/e_1$ and Assumption 3, $I_1^S = e_1/(2\varphi) < \bar{I}$. Hence, $\widehat{E}^P / \widehat{E}^S = 2\bar{I}/I_1^S > 1$. The banker privately prefers to overinvest in a risky loan portfolio (at Risk Level 1) because she does not internalize the negative externalities from shirking. Hence, the lower bound on equity for implementing Risk Level 0 becomes tighter, that is $\widehat{E}^P > \widehat{E}^S$. That means a banker with $E \in [\widehat{E}^S, \widehat{E}^P[$ will be tempted not to screen the loans and sacrifice the rate of return on her investment for a larger investment size. Finally, a highly leveraged bank has incentives to shift risk to the deposit insurance fund, which is not allowed by the social planner.

2.3 Nondilutive CoCo bonds and (constrained) efficiency

We now examine how the constrained social optimum defined in Proposition 6 can be implemented using a security characterized by a price P and state-contingent payoffs $\{r(R), r(R'), 0\}$. Without losing generality, we allow the banker to issue, alternatively, CoCos, uninsured subordinated debt, or non-voting shares.

Like in the simplified model, a CoCo bond is a debt-like security and pays a face value $r(R) = F$ in the R state, while converting to a fraction λ of the bank's equity and worth $r(R') = \lambda(R'I - D)$ in the R' state. A CoCo bond can be nondilutive if it is junior to equity, if its conversion results in a transfer from CoCo investors to equity holders. We show in the next proposition that the constrained social optimum can be implemented using a nondilutive CoCo bond (proof in IA B.11).

Proposition 7. The constrained social optimum can be implemented using nondilutive CoCos that lose value in the R' state, in which case the bank is still a going concern.

A constrained-efficient CoCo bond is nondilutive and loses value upon conversion, a feature that is necessary when the constrained optimum involves Risk Level 1. Indeed, when Risk Level 0 is infeasible and not part of the constrained social optimum, restricting CoCo bond designs to dilutive ones will result in ex-post risk-shifting. On the other hand, when the constrained social optimum entails Risk Level 0, the R' state is off the equilibrium path, so any $\lambda \in [0, 1]$ can induce screening efforts. Therefore, nondilutive CoCo bonds, including PWD CoCos, can produce Risk Level 0 for banks with

$E > \widehat{E}^S$. In addition, as noted in Lemma 2, the bank should remain solvent in the R' state. Otherwise, the banker would receive a zero payoff as the equity holder upon CoCo conversion and would engage in risk-shifting to avoid the R' state.

2.4 Capital regulations for implementing the constrained optimum

The existence of negative externalities provides a rationale for prudential regulations. Even if we have shown that properly designed CoCo bonds can restore the constrained social optimum, differently from a social planner, regulators have limited control over the features of the various CoCo contracts issued by the banks in their jurisdiction. What a regulator can do is to set limitations on a bank's leverage decisions ex ante, to induce banks to choose adequate CoCo contracts. In the next proposition, we show that CET1 and Tier 1 capital requirements are complementary and can together *partially* implement the constrained social optimum. However, differently from the case of the constrained optimum, not all banks are viable, and those with high leverage will be shut down by the regulator.

Proposition 8. To correct the banker's incentives, the regulator should impose both a capital requirement $D/I \leq 1-\mu$, which limits the use of insured deposits, and a CET1 requirement $E/I \geq \nu$, which demands sufficient common equity financing of the bank's investment, where

$$1-\mu = \begin{cases} e_1/e_2 & \text{if } E < \widehat{E}^S \\ e_0/e_2 & \text{otherwise} \end{cases} \quad \text{and} \quad \nu = \begin{cases} E/I_1^S & \text{if } E < \widehat{E}^S \\ \dfrac{G}{pq} - e_0 & \text{otherwise.} \end{cases}$$

While banks with equity $E < \widehat{E^S}$ will issue nondilutive CoCos that lead to Risk Level 1, better-capitalized banks will issue CoCos that result in Risk Level 0. The regulator closes a bank if it fails to meet these requirements, that is if $D > \widehat{D}^S$, where $\widehat{D}^S = \max\{\frac{e_0}{e_2} I_0^P, \frac{e_1}{e_2} I_1^S\}$.

Proposition 8 (proof in IA B.12) introduces a combination of optimal capital requirements to ensure banks issue sufficient common equity and CoCo bonds, in order to partially restore the constrained social optimum.[21] In particular, the banker's incentives and the investment size are corrected if a bank can meet the capital requirements. Otherwise, the bank will be shut down.

The CET1 requirement prevents a bank with $E \in [\widehat{E}^S, \widehat{E}^P[$ from engaging in either moral hazard action. The social optimal allocation if $E \geq \widehat{E}^S$ is sustained through the inducement of the bankers to issue CoCo bonds under

[21] It is worth noticing that μ and ν depend on the banker's equity endowment.

Design 0, which prevents both moral hazard actions. For a bank with $E < \widehat{E}^S$, it is socially optimal to increase investment at the cost of reducing screening. Correspondingly, the CET1 requirement encourages such a bank to issue the nondilutive CoCo bonds that produce Risk Level 1. In addition, the CET1 requirement limits negative externalities associated with reduced screening by preventing the bank's overinvestment in a loan portfolio of Risk Level 1.

Proposition 8 also recommends shutting down a bank with $D > \widehat{D}^S$ to prevent it from shifting risks to deposit insurance.[22] The capital requirement μ is used to compel banks to maintain debt levels below the threshold that would trigger risk-shifting incentives. Putting a cap on a bank's debt ratio can be interpreted as requiring the bank to keep a minimum Tier 1 ratio.

In summary, the CET1 requirement ensures that a bank chooses the CoCo design that produces the constrained-efficient risk level. If CoCos are AT1 capital, the Tier 1 requirement suggests that a bank should issue a sufficient amount of CoCo bonds to prevent gambling for resurrection. We highlight that the role of CoCo bonds in correcting incentives relies on bankers' equity capitalization, which means CoCo bonds are not substitutes for common equity. In fact, the CET1 requirement is needed to ensure that CoCo bonds are not an abuse of Tier 1 regulatory capital.

3. CoCos versus Other Forms of Bank Regulatory Capital

In this section, we compare CoCos with nonvoting shares and subordinated debt, because they can absorb losses for senior debt holders and are also considered regulatory capital.[23] This comparison enables us to investigate CoCos' AT1 designation in the regulatory stack.

To aid intuition, we first analyze the simplified setup with fixed investment size, which is then generalized as per the previous section. The following proposition summarizes the risk-taking incentive induced by each of the three security classes in the simplified setup with a unit investment size.

Proposition 9. For a bank with $E < \frac{G}{pq} - (R-1)$, CoCos perform equally as well as nonvoting shares and dominate subordinated debt, because they prevent risk-shifting.

If $E \in [\frac{G}{pq} - (R-1), \frac{(R-D)G}{p(R-R')} - (R-1)[$, CoCos dominate nonvoting shares by inducing a screening effort and perform equally as well as subordinated debt.

If $E > \frac{(R-D)G}{p(R-R')} - (R-1)$, CoCos, subordinated debt, and nonvoting shares perform equally well and prevent both moral hazard actions.

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22 By contrast, all banks are open and operated to maximize the social value in the constrained social optimum.

23 In our model, nonvoting shares can be seen as external equity and distinct from the internal equity of the banker. This view allows us to highlight a potential conflict of interest between internal and external shareholders.

The intuition of Proposition 9 (proof in IA B.13) is as follows. First, for a poorly capitalized bank (with $E < \frac{G}{pq} - (R-1)$), shirking is inevitable and the focus is to avoid risk-shifting. Subordinated debt, however, features the same face value across the R' and R states, leaving the banker in the R' state either nothing (if bankruptcy occurs) or only a low payoff (if the bank is not in bankruptcy but needs to repay outside financiers as much as it would in the R state), which will induce the banker to gamble for resurrection. The payoff of nonvoting shares and (nondilutive) CoCos, by contrast, can be kept low in the R' state, making the two securities suitable for avoiding risk-shifting.

Second, compared to CoCos, nonvoting shares require more skin-in-the-game from the banker to induce a screening effort because nonvoting shares entail distributing a fixed fraction of the total equity value to external financiers across the R' and R states. This restriction can leave the banker (i.e., the insider) with too little stake in the R state relative to the private benefit, G, dampening her incentive to screen loans. CoCos, on the other hand, can preserve more value for the banker, with their debt-like feature in the R state, and can induce the screening effort more effectively.

Finally, for a bank with sufficient equity capital, $E > \frac{(R-D)G}{p(R-R')} - (R-1)$, the moral hazard problems are muted and a Modigliani-Miller result emerges in that the bank's value does not depend on the form of its financing choice. Figure 7 illustrates how the bank's value changes with different securities.

CoCos' advantage comes from their flexibility of design, which can either enable better risk management or allow for more financing capacity. As a result, for the whole range of E, the CoCo as a financing contract is never dominated by subordinated debt or nonvoting shares and can strictly outperform each of those two securities in some ranges of E. On the other hand, it should be noted that, *for a given E*, CoCos are not uniquely optimal in terms of generating the highest possible bank value. This feature remains in the general setup, and suggests that CoCos can be, but are not necessarily, part of an optimal regulatory framework.

Turning to the fully-fledged model, we show that CoCos can outperform subordinated debt and nonvoting shares, as neither security can provide the constrained social optimum (proof in IA B.14):

Corollary 3. In the fully-fledged model, neither subordinated debt nor nonvoting shares can produce the constrained social optimum. In particular, it is never feasible to induce Risk Level 1 with subordinated debt, and the constrained optimal investment size at Risk Level 0 cannot be achieved with nonvoting shares.

The intuition of this result is immediate: the banker's investment technology generates two ex post states in which the returns are positive, R and R'. CoCos (and any other convertibles for that matter) allow for flexible payoffs across the two states, to provide efficient allocations. On the one hand, nonvoting shares, while allowing a state-dependent payoff, restrict it to a given

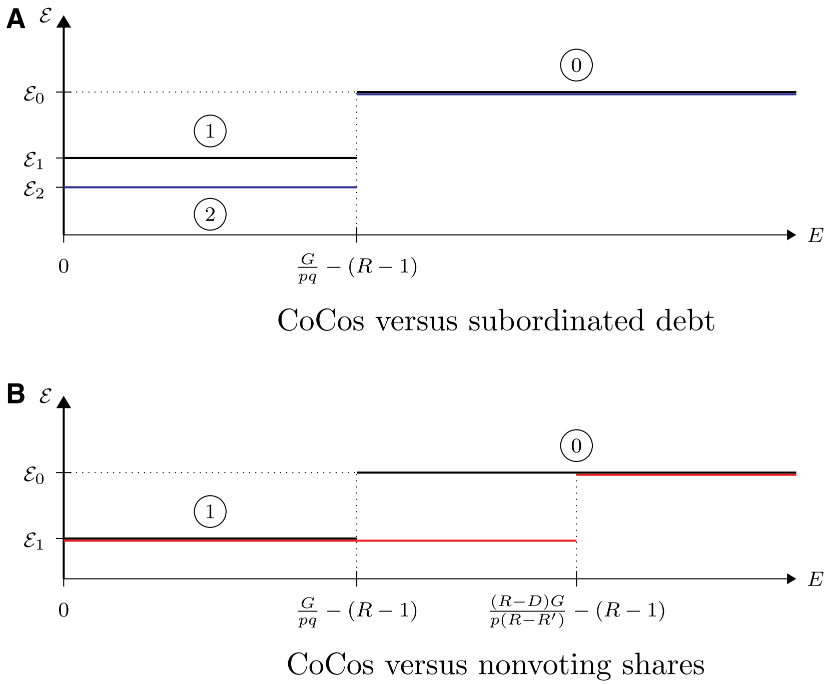

Figure 7
Security comparison: The bank's value and equity capitalization
The figure plots against the bank's paid-in equity, E, the banker's net value, $\mathcal{E}$, for CoCos versus subordinated debt in panel A, and CoCos versus nonvoting shares in panel B. The black line represents the net value achievable with CoCos; the blue line represents subordinated debt; and the red line represents nonvoting shares. ⓪ is associated with contracts that lead to no moral hazard, ⓪ with contracts that lead to shirking, and ⓪ with contracts that lead to shirking and risk shifting.

proportion of the residual value of the bank. Requiring the banker to distribute the same fraction of the bank's residual value in the R and R' states tightens her incentive constraint, which in turn reduces the investment size at Risk Level 0, pushing it below the constrained-efficient level. Subordinated debt, on the other hand, imposes a constant face value across the two states and makes risk-shifting inevitable. Indeed, Lemma 2 shows that the bank must remain solvent in the R' state to prevent risk-shifting, so that debt cannot be risky. However, if the debt is risk-free and $r(R) = r(R')$, the constrained optimum will not be achievable if it entails Risk Level 1.

Because the optimally designed CoCos in our model can outperform subordinated debt in correcting incentives, such CoCos—despite being nondilutive—should rank higher than subordinated debt in the regulatory capital stack. Because subordinated debt is treated as Tier 2 capital in certain jurisdictions, it is justifiable to grant CoCos the AT1 designation. CoCos' AT1 designation is also justifiable because nonvoting shares can be considered as Tier 1 capital if they differ from common stock only in terms of voting rights. On the other hand, the correction of risk-taking incentives by such CoCos can be partial, in the sense that they avoid risk-shifting but may still allow for shirking, and so CoCos are not on a par with common equity. Overall, our results show that the AT1 designation is appropriate.

4. Conclusions

In this paper, we empirically document the prevalence of nondilutive CoCos—practically all AT1 CoCos issued by G-SIBs tend to be nondilutive—despite the initial envisioning that CoCos need to be dilutive to penalize and deter bank shareholders' risk-taking. To understand the prevalence of nondilutive CoCos and the risk-taking incentives they provide, we build an agency model with two subsequent moral hazard actions: a banker may slack on its loan-screening effort and take on further risks to gamble for resurrection when the lack of screening has already resulted 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 preserves 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 nondilutive 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.

Our analysis reveals that the design of CoCos can crucially depend on the equity capitalization of the bank. Since the nondilutive CoCos tackle only the ex post risk-shifting and therefore concede less rent to the management/owners of the bank, they generate more pledgeable income and relax the bank's financing constraint. 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. To provide a normative perspective, we also allow for negative externalities resulting from the lack of banker screening so that a difference emerges between the private optimum and (constrained) social optimum. We show that the constrained social optimum can be implemented by nondilutive CoCos when the bank has low equity. CoCos can also outperform other loss-absorbing capital instruments, such as nonvoting shares and subordinated debt.

We provide a somewhat moderate view within the policy-making debate on the usefulness and 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. However, we are not entirely pessimistic and do not consider nondilutive CoCos to necessarily induce risk-taking either. While we consider the AT1 designation appropriate for CoCos, we also believe that more can be done to help CoCos fulfill their role in promoting financial stability, and whether that is attainable crucially depends on the equity capitalization of banks.

Code Availability

No new code was generated in support of this research.

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