FINANCE

MACRO RISK

Risk and Macro Finance
Working Paper Series

No. 2017-01

Regulatory Forbearance, CoCos, and Bank Risk-Shifting

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Regulatory Forbearance, CoCos, and Bank Risk-Shifting

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June 28, 2017

Abstract

Contingent convertible capital (CoCo) is a debt instrument that converts to equity or is written off if the issuing bank fails to meet a prespecified threshold. We examine the setting when conversion is subject to regulatory discretion. A regulator that faces conversion costs will only convert CoCos if it causes the bank's equity level to exceed a threshold such that it chooses to liquidate its bad assets rather than to gamble for resurrection. But if the conversion costs are high enough, or if conversion does not switch a bank's decision, regulatory forbearance is observed. We endogenize the conversion costs by casting them as bank run probabilities. The initial asset choice of the bank depends on what it anticipates the regulator will do, as well as how much CoCos are in place. Only when there are relatively few CoCos will banks be induced to choose safe assets ex ante, which undermines the loss absorption capacity of the CoCos.

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1 Introduction

In the banking literature, regulatory forbearance shows up in many forms. There is always a tradeoff between toughness and softness, but the context differs. It may show up as keeping a bank open when it is better to close it down. It may also show up as regulators having to intervene in one form or another such as by lowering interest rates, rolling over loans, injecting capital, or bailing out banks whenever they are at the verge of insolvency in order to avoid a financial system meltdown. Banks know that by collective action, they may force the regulator to forbear on tough decisions. However, observable regulatory actions may have unintended consequences, such as sending signals when they are not wanted. As a result, many attempts have been made to find out how the regulator is able to commit to tough solutions. Reputation-saving is one driver, but rules-based regulation is another. Of particular note is the introduction of CoCos in order to commit the regulator to an intervention when it is necessary, by letting conversion be driven not by their own decisions, but by publicly observable market-based measures such as share prices.

One of the positive points of CoCos is to improve a bank's loss absorption capacity in the event of a crisis. However, for this to happen, CoCos must first be converted. In general, CoCos convert in one of two ways: when the bank's book-based or market-based equity ratio falls below a prespecified threshold, or when the regulator decides that the bank is close to the point of nonviability. Regardless of the design of the CoCo, the bank's skin in the game upon conversion increases. But conversion is not without consequences. For instance, in **?**, we argued that conversion would lead to a possible increase in the probability of bank runs because conversion is a public matter and sends a signal about asset quality. For this reason, regulators may be hesitant to force conversion even when necessary, as they shoulder costs of conversion.

As it is not always true that CoCos convert automatically, it may fall short of being both a disciplining device for the banks and a committment device for regulators. In this paper, we take the stance that CoCo conversion is also vulnerable to regulatory forbearance. This is because while a conversion improves a bank's incentives by increasing its skin in the game as its loss absorption capacity increases, it also exposes the regulator to conversion costs. The regulator has to weigh these against the increased social welfare from improving a bank's incentives. We show that if the regulator's cost of conversion is high enough, then she will forbear on the conversion. Forbearing

on conversion means that CoCos are not going to be useful for improving loss absorption. On the other hand, converting too readily may encourage ex ante risk shifting,[1] unless there are very few CoCos, in which case they are also not going to significantly improve loss absorption capacity.

We illustrate these ideas with a three-period model, where we allow the bank to have actions at two points in time: the initial asset choice at $t = 0$, and a choice between gambling for resurrection and liquidating assets at $t = 1$. In short, we consider the bank's typical decisions in its regular course of business, but examine how these decisions will be affected by the presence of CoCos. If the regulator deems it necessary, she may cause CoCo conversion. In this model, "necessary" means that conversion improves the bank's skin in the game sufficiently to lead the bank to make socially optimal decisions. As such, even though regulator cannot directly control the initial choice of assets, she may be able to do so indirectly. However, the circumstances when that occurs are very limited. In particular, there is a threshold level of skin in the game that the bank must exceed in order to be induced to make socially optimal choices. We find that there are times that even a conversion is not enough to bring the bank's skin in the game up to the threshold. In such cases, one will observe regulatory forbearance, as conversion will only incur costs without bringing social benefits.

We endogenize the regulator's cost of conversion by adding in a simple updating model of depositors' beliefs. That is, since conversion is publicly observable, all the agents, including the depositors, are made aware of this information. The assumption that safe assets will never induce conversion means that conversion definitely indicates that the bank has invested in the risky assets at the very beginning, and increases doubt in the depositors' minds as to the bank's survival. This causes the threshold required belief in the return of the risky asset to increase.

The bank's $t = 0$ decision ultimately depends on its expectations regarding the level of conversion costs faced by the regulator. In a setting with imperfect information regarding the regulator's costs of conversion, we show that the only way that safe assets would be chosen at $t = 0$ is if the CoCo issuance is sufficiently small. However, doing so negates the increase in loss absorption capacity that CoCos are intended to have. This highlights the tradeoff between inducing a safe choice ex ante, and increased loss absorption capacity ex post.

The remainder of this paper is structured as follows. Section 2 discusses the related literature.

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[1]This depends on the design of the CoCo. For instance, convert-to-equity CoCos may be sufficiently dilutive as to prevent this.

Section 3 sets up the game, Section 4 solves the game up to $t = 1$ for various cases. Section 5 endogenizes the regulator's conversion costs. Section 6 solves the game up to $t = 0$ under imperfect information regarding the type of regulator. Section 7 concludes. Appendix A explores the role that dilution plays in $t = 0$ decisions, while Appendix B contains calculations that are absent from the text.

2 Review of related literature

? is an early paper on the discretionary power of regulators. Central to their paper is that closure is deemed a major instrument of bank regulation, which may deter banks from making risky asset choices. The regulator's decisions involves accounting for opportunity costs of the asset that are foregone if the bank is closed down. For a cost-minimizing regulator, this leads to conflicts between what is privately optimal for the regulator and what is socially optimal. In this sense, regulators may not always be welfare-enhancing, as their presence leads the banks to choose actions that are not first best.

The standard view is that regulatory discretion encourages moral hazard on the part of the banks but **?** show that a regulator's committment to bailing out institutions during a crisis may reduce the possibility of moral hazard from banks. In their model, banks are maximizers of their charter value. If the bank's charter value is sufficiently high, the shareholders will choose safer assets. A shock will naturally decrease a bank's charter value, which may encourage risk-taking. In this situation, a regulator's commitment to bail out[2] the bank will automatically increase the bank's probability of survival, which increases the charter value, and leads to safer choices after the shock. However, this will only hold if the bailout policy is contingent on the realization of the state of nature.

Another strand in the regulator discretion literature is that of forbearance being done to manage information. **?** consider the case where regulatory forbearance may come about as a result of regulators trying to manage their reputation. In their model, the regulator can imperfectly screen the quality of banks, and grant banking licenses based on their findings. The proportion of sound banks is therefore a direct consequence of the regulator's screening ability. Closure occurs only if

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[2]A bailout in their context is to provide the troubled bank with sufficient funds to repay the depositors and carry on operations.

auditing leads to evidence about the poor state of the bank. If the regulator decides to close down a bank, it causes the agents in the economy to infer that the regulator's screening technology is bad. If the initial level of the regulator's reputation is low enough, closure may lead to contagious bank failures, as the belief about the proportion of sound banks is affected as well. Therefore, even though closing down the bank may be a socially better option than keeping it open, regulators will choose to forbear because of the potential damage to their reputation as a good auditor, and the subsequent impact on the financial system.

Closure is not the only action that can be done by regulators. **?** explore the impact of including bailouts as part of the regulatory toolkit. In their model, the regulator has three actions: liquidate, forbear, or bail out. Similar to **?**, the action that the regulator takes inadvertently gives a signal to the depositors about the quality of the bank. However, in the setup of **?**, the preference of the regulator will depend upon her cost of injecting capital. A high cost regulator will never inject capital, and so will only choose between liquidation and forbearance. On the other hand, a low cost regulator will choose between bailouts and forbearance. In their model, the risk-shifting tendencies of banks will depend on their assessment of the type of the regulator they are dealing with. However, it turns out that regulators can take advantage of the uncertainty about their type to discourage bank misbehavior and manage depositor expectations at the same time.

In addition to liquidation, forbearance and bailouts, another regulatory tool is the bail in of outstanding liabilities. **?** explore the regulator's dilemma on choosing the optimal amount of bail-in, while abstracting from the bank's risk-shifting incentives. In their model, the amount of bail-in triggered by the regulator is discretionary but publicly observable. This directly affects both the depositors' decision to withdraw, and the outside buyers' market valuation of the bank's assets. They reason, like **?**, that runs occur upon the revelation of previously hidden negative information about the bank's asset quality. As the regulator knows this, she has an incentive to hide bad information by bailing in an amount that is consistent with if she had obtained good information. However, not bailing in an sufficient amount is detrimental to social welfare. **?** argue that if regulators were able to credibly commit to an optimal bail in rule based on public information, they can be tough without provoking runs, as public information does not necessarily reveal private information. They champion CoCos as a way to sidestep this pooling problem. However, CoCos do not necessarily convert automatically, as most of them have discretionary triggers within the

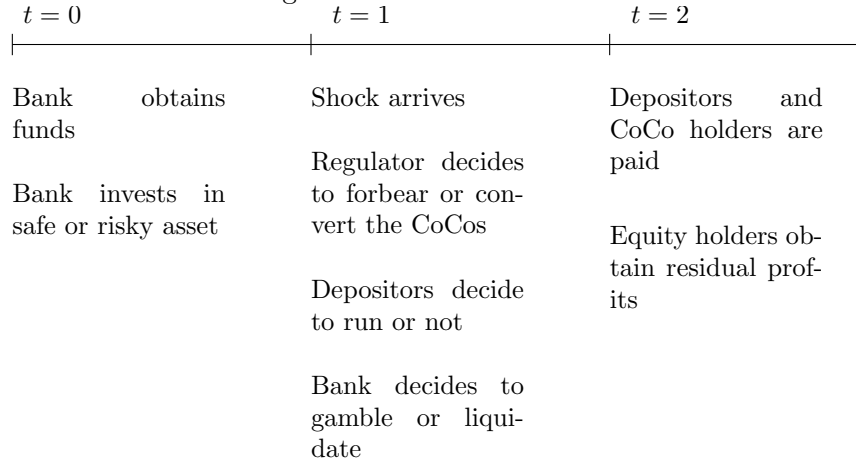control of the regulator, so that undermines their role as a commitment device.

? examine the tradeoffs that a regulator faces when the banks in the system are able to herd by choosing to invest in similar industries. The banks are incentivized to choose low correlation of investment,if the surviving bank is allowed to purchase the failing bank. It is is still possible for both banks to fail even if they invested in different assets, but if both banks fail, the regulator must choose between bailing out the two banks itself, or letting both banks be acquired by an outside investor. The problem of the regulator arises from the bailout option: if the costs of bailout is not very high, then the regulator's declaration to choose the acquisition option is not credible, because by assumption, letting outside investors take over the bank lead to efficiency losses. They show a region of time inconsistency, where the regulator is able to credibly induce banks to choose low correlation ex ante, but upon the occurence of the both-fail state, the regulator will choose to bail out the banks in the end. However, they do not look into effects on future reputation, they use a one-shot game setup.

? explore the time inconsistency problem in the context of a maturity mismatch by banks. The regulators bail out the banks in their model by setting very low interest rates. They highlight the potential cost faced by the regulator in losing credibility. However, doing so is always at the expense of the nonbank agents. Like **?**, **?** find that the lack of committment by the central bank on interest rate setting creates moral hazard in banks depending on the expectation of banks regarding the stance of the central bank. If they expect that the central bank will adopt a tough stance, banks will choose to hoard liquidity, while if the central bank is expected to have a soft stance, the banks will collectively choose to incur maturity mismatch as the optimal strategy at that point of a regulator is to bail out all the banks at once. They show that imposing capital regulation is a means of curtailing the bank's mismatch situation when the regulator has limited commitment.

3   The model

We are interested in the factors that affect a regulator's decision on CoCos, when the CoCos have a discretionary trigger. In order to do so, we use a model where the bank and the regulator take turns in making decisions about where to invest and whether to forbear. Figure 1 illustrates the timeline of events of our model.

Figure 1: Timeline of Events

$t = 0$	$t = 1$	$t = 2$
Bank obtains funds	Shock arrives	Depositors and CoCo holders are paid
Bank invests in safe or risky asset	Regulator decides to forbear or convert the CoCos	Equity holders obtain residual profits
	Depositors decide to run or not	
	Bank decides to gamble or liquidate	

In this game, we take the bank's capital structure as a given. We give the bank two consecutive chances to commit moral hazard after obtaining its funding: one on the choice between a safe and a risky asset, and another on the choice to gamble for resurrection or liquidate the bad fraction of the risky asset. The bank's second decision depends upon whether its debt level would meet a certain threshold. This is where CoCos are potentially useful, as when the regulator forces conversion, the bank may be able to surpass the threshold debt level. Therefore, even if there are two types of CoCos in practice,[3] we only consider the type that is written off the issuing bank's balance sheet, as the bank's liability after a conversion will be the same regardless of the type of CoCo issued. In turn, the bank's initial choice between the safe and the risky asset depends on the proceeds from the second decision.

CoCos convert when the bank's equity ratio falls below a threshold ratio. To justify conversion, we introduce shocks on the probability of obtaining good returns of the risky asset into the model. We examine the no-shock case (henceforth referred to as the benchmark case) before cases that involve shocks in order to focus on the essential drivers of regulatory forbearance. Also, even though the bank raises its funds from both depositors and CoCo holders, we initially abstract away from the possibility of bank runs to focus on the interaction of the bank and the regulator. But since conversion is publicly observable, it may alter the beliefs held by the creditors of the bank and lead to runs. We address this issue in a later section. The regulator needs to take the changes in

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[3]One of them is the principal writedown CoCo, where the CoCos are fully or partially written off upon the occurence of a trigger event. The other is the equity-converting CoCo, where the CoCos are converted to equity at a prespecified ratio, and may be dilutive to the original shareholders.

these beliefs into account in deciding whether to convert CoCos. At the same time, CoCo conversion alters the bank's capital structure, which means that conversion may be used by the regulator to nudge banks into performing socially optimal actions ex ante and ex post.

3.1 Setup

We develop a stylized three-period model, setting up a game between a regulator and a CoCo-issuing bank.[4] The bank moves first, followed by the regulator, and then the bank again. During the regulator's turn, she can decide whether to convert the CoCos or to forbear on conversion. We model it this way as we believe that CoCo conversion is at the discretion of the regulator,[5] even in the presence of automatic conversion clauses, because of the discretion unavoidably embedded in accounting rules. This is the more relevant case because none of the CoCos issued to date have a market-based trigger. Figure 2 illustrates the game.

Figure 2: Interactive Game Between Bank and Regulator
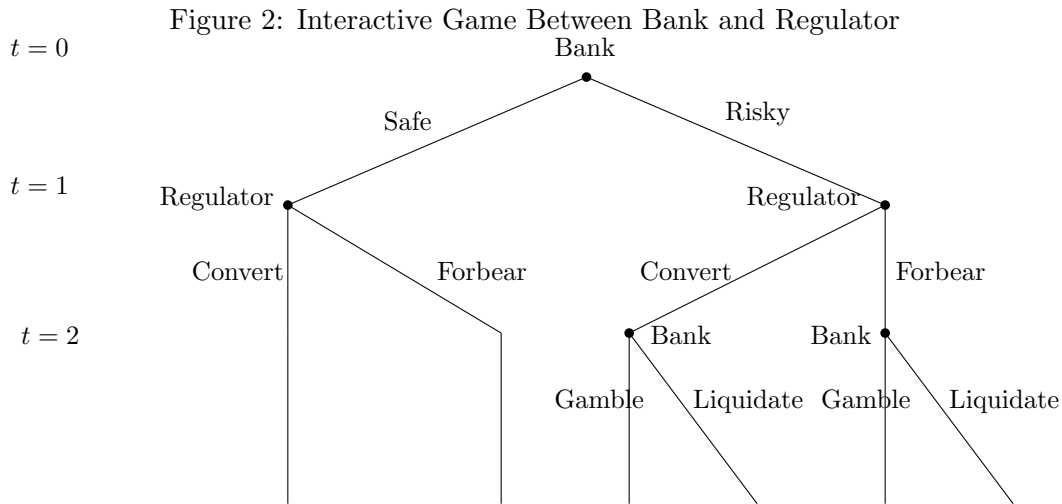
3.1.1 Period $t = 0$

At $t = 0$, the bank raises funds from a continuum of risk neutral creditors: (wholesale) depositors[6] who collectively invest D, and CoCo holders who invest a total of C. In addition, the bank's owner-manager invests E of his own equity. The initial amounts are normalized such that $D + C + E = 1$.

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[4]The model builds on **?**, but they do not put it in a game-theoretic context.

[5]All CoCos issued since the BIS published its new capital definition rules must have a point of nonviability clause under which the regulator can force conversion if the CoCo is to qualify as Additional Tier 1 capital.

[6]By wholesale depositors, we mean those that are not covered by deposit insurance. One may also think of them as holders of other forms of short term funding that are susceptible to rollover risk, such as commercial paper.

We do not delve into the optimal capital structure as our focus is on the interaction between the banker and the regulator for a given capital structure. Moreover, banks are subject to capital regulation, and as such, maybe unable to choose their capital structure optimally, at least, not instantly.

To entice the depositors and the CoCo holders to invest their money in the bank, they are promised a return $r > 1$ at $t = 2$.[7] There is no deposit insurance, but we assume that depositors hold beliefs regarding the bank's prospects such that the depositors' participation constraints are assumed to be satisfied. That is, we assume that on average, depositors break even based on their own beliefs. As a result, the depositors are passive agents in the model.

Upon receiving funds from the aforementioned agents, the bank arrives at its first decision point: the choice of where to invest these funds at $t = 0$. For simplicity, there are only two available assets for the bank: a safe one and a risky one. The safe asset delivers a return R_s with certainty, and is enough to pay off the amounts promised to depositors and CoCo holders at $t = 2$. That is,

$$R_s - r(D + C) > 0. \tag{1}$$

The risky asset is a portfolio of correlated loans that may turn out to be good collectively with probability $1 - q$ and bad (equally collectively) with probability q. We assume that the banks take the proportion q as given at $t = 0$. When the loans turn out to be good they yield $R_r > R_s$ with certainty; if the loans turn out to be bad they yield R_r with probability p and 0 otherwise. Thus, the expected return of the risky loan portfolio (which we will refer to consistently as the risky asset) at $t = 0$ is

$$(1 - q)R_r + qpR_r = (1 - q + qp)R_r. \tag{2}$$

So the risky asset delivers return R_r with probability 1-q if the loans are good, and with probability p if the loans are bad, for an overall probability of a return R_r equal to $s = 1 - q + qp$. As a consequence we can say that the loan package delivers return 0 with probability 1-s. Furthermore we assume that the risky asset has negative expected net present value, in the sense that the expected return

of the risky asset is less than the promised returns to the depositors and the CoCo holders. That is,

$$sR_r - r(D + C) < 0. \tag{3}$$

Therefore the risky asset is socially less desirable than the safe asset.

However, because the bank enjoys limited liability, the private returns of the risky portfolio actually exceeds its social value: when the loans yield zero, the bank escapes having to pay its creditors. In line with Merton's famous phrase, because of limited liability the bank can effectively put its downside risk to its creditors ?. The following relation holds between the private and public risky asset returns and safe asset returns:

$$s(R_r - r(D + C)) > R_s - r(D + C) > 0 > sR_r - r(D + C), \tag{4}$$

The social return counts depositor losses and the private return does not. Note that the private return of the risky project can be written as

$$s(R_r - r(D + C)) = sR_r - r(D + C) + (1 - s)r(D + C), \tag{5}$$

which is equal to the social return of the risky project, plus what amounts to the Merton put $(1 - s)r(D + C)$; this arises because of limited liability (?), limited liability implies a put option written by creditors to equity holders.

3.1.2 $t = 1$: Conversion rules

At $t = 1$, adverse information regarding the bank's expected returns may arise, that comes to the attention of both the bank and the regulator. In this model, they come in the form of shocks to the composite probability s of the risky asset. If the size of the shock is such that the bank's equity ratio falls below the trigger ratio associated with the CoCo, the CoCo should in principle be converted by the regulator. However, the regulator has discretion over the course of action: she has the ability to convert the CoCos even without new information, and she can forbear on conversion if she obtains new negative information regarding the bank. In this model, provided that the regulator refrains from forbearance, the regulator's conversion decision is aligned with the automatic conversion rules.

We discuss the conversion rules here.

Let τ be the trigger ratio that the bank's equity ratio must exceed in order for the CoCos to remain unconverted. The trigger ratio is independent of the *amount* of CoCos issued by the bank. The equity ratio equals net assets divided by total assets.[8] At any time before $t = 2$, the expected value of the assets at $t = 0$ is used if no new information arrives. However, in the event of new information regarding the probability of obtaining returns by $t = 1$, the $t = 1$ expected value of the assets will be used. Both the bank and the regulator learn of the new information at the same time, although the regulator has discretion over the conversion of the CoCos. The parameter values at $t = 0$ are assumed to satisfy the trigger ratio τ such that CoCo conversion will not be triggered at the start of the game, regardless of the bank's initial choice. This implies:

$$\frac{R_s - r\left(D + C\right)}{R_s} \geq \tau \tag{6}$$

if the bank had chosen the safe asset and

$$\frac{sR_r - r\left(D + C\right)}{sR_r} \geq \tau \Leftrightarrow s \geq \frac{r\left(D + C\right)}{R_r\left(1 - \tau\right)} \tag{7}$$

if the bank had chosen the risky asset.

3.1.3 $t = 1$ and $t = 2$: Bank risk-taking and final payment

At $t = 1$, the regulator and the bank observe whether new adverse information regarding the economic conditions arrive. If there is bad news, the regulator chooses whether to convert the CoCos, or forbear on conversion. Without new information or after good news, the regulator has no reason to choose conversion, because the expected value of the assets at $t = 1$ would be the same or better than (after good news) that of $t = 0$, so that the trigger ratio remains satisfied. Upon conversion, the rC CoCos are written off.[9]

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[8]To keep things simple, we have assigned the same risk weights to any asset chosen by the bank in our model. We may also choose to have different risk weights for the assets, but as risk weights are only constants, varying them would not materially affect the results.

[9]The distinction between the two CoCo types is irrelevant at $t = 1$, as the bank's $t = 1$ decision depends only on its outstanding liabilities, and not on the allocation over old and new shareholders. Of course, the type of CoCo influences a bank's $t = 0$ decisions. If the CoCo was an equity converter, there is a conversion ratio that would lead the bank to choose the safe asset over the proceeds of the liquidated risky one. Calculations are presented in Appendix A.

After the regulator's decision, the bank arrives at its second decision point regarding its bad loan: gamble for resurrection or liquidation. Gambling for resurrection does not change the probability of recovery that a bank faces. Instead, the bank retains the bad loans on its balance sheet. This is an attractive choice for the bank because it enjoys an implied Merton put that arises from limited liability. On the other hand, when a bank liquidates, we assume that it sells off the bad loans at a loss and relends the proceeds to a safe project, as in **?**. We assume that liquidation is costly, that is, it always yields a return $0 < \lambda < 1$ for every unit of asset. Therefore, safe assets are never liquidated because $R_s > \lambda R_s$. The same is true for the $1 - q$ fraction of good loans of the risky asset, because $R_r > \lambda R_r$. Henceforth, decisions on gambling or liquidation at $t = 1$ only ever pertain to the bad loans of the risky portfolio.

Finally at $t = 2$, if the bank survives, the creditors are paid in order of seniority, and the bank owner/manager receives any residual profits.

4   Backward induction at $t = 1$

In order to find out the bank's ultimate choice at $t = 0$, we must resolve the $t = 1$ events first. We therefore solve the game backwards from $t = 1$ as decisions are no longer made at $t = 2$. The bank can choose between gambling or liquidation but only after the regulator has decided between conversion and forbearance. Therefore, the regulator may be able to influence bank's choice, as the regulator's decision to convert the CoCos alters the level of the bank's skin in the game.

The rationale of CoCo issuance is to improve the bank's equity position in times of shocks. We discuss the benchmark case (without the shocks) before the cases with shocks. As previously mentioned, the benchmark case allows us to focus on the essential driver of regulatory forbearance. It also sheds light at $t = 0$, when decisions have to be made when the shocks are not known. Finally, the benchmark case allows us to examine how the bank anticipates the regulator's action in the simplest setting, which feeds back into the $t = 0$ decision.

4.1 The benchmark case

4.1.1 The bank's choice between gambling and liquidation at $t = 1$

Consider first the expected returns of a bank that has decided to gamble for resurrection at $t = 1$. As in (3), the expected return from the investment is

$$(1 - q + qp) R_r = s R_r, \tag{8}$$

where p is some low probability of recovering the q bad loans. Therefore, for given liability B, the expected returns from gambling for resurrection is $s(R_r - B)$. On the other hand, the expected returns of a bank that has decided to liquidate the bad loans is

$$(1 - q) R_r + q\lambda R_r = (1 - q + q\lambda) R_r \equiv s^\lambda R_r, \tag{9}$$

with s^λ is the recovery rate on the entire risky asset. We make the additional assumption that

$$s^\lambda R_r > r(D + C), \tag{10}$$

i.e. the bank is solvent in this case.[10] We may then write, for liability B, the bank's expected returns from liquidation is $s^\lambda R_r - B$. For the fraction q of bad loans in the risky portfolio, liquidation yields λR_r with certainty, as opposed to obtaining R_r with some low probability p. We assume that $\lambda > p$ so that the regulator prefers that the bank choose liquidation over gambling. However, because of limited liability, the bank finds gambling for resurrection attractive. In particular, under gambling for resurrection, B only has to be paid with probability s. That is, the bank benefits from the Merton put implied by limited liability. On the other hand, under liquidation, B is paid with certainty, because of the assumption in (10). Therefore, for some outstanding liability B, the bank will only choose liquidation over gambling if the following condition is satisfied:

$$s^\lambda R_r - B \geq s(R_r - B) \tag{11}$$

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[10]In this model, the maximum amount of liabilities that the bank has at any given time is $r(D + C)$, such that we can generalize to any B in the $[rD, \; r(D + C)]$ range.

We call (11) the liquidation incentive constraint (LIC). (11) further simplifies to

$$B \leq \left(\frac{\lambda - p}{1 - p}\right) R_r \equiv B^*, \tag{12}$$

where B^* is the threshold amount of liability that the bank should not exceed in order for the bank to choose liquidation over gambling.

We can equivalently cast the LIC in terms of equity. By doing so, we can more clearly see the role of the bank's level of skin in the game in the choice that it makes. We add the expected return of a bank's asset conditional on the risky choice being taken (sR_r) to both sides of (12) in order to obtain the critical equity value E^*.

$$sR_r - B \geq sR_r - B^* \equiv E^* \tag{13}$$

E^* is the equity level that corresponds to the maximum debt threshold B^* defined in (12). Banks will gamble when their skin in the game falls short of E^* and liquidate otherwise.

4.1.2 The regulator

A regulator may be classified according to different dimensions: either welfare-maximizing or cost-reducing as in **?**, with a good or bad audit technology as in **?**, or with a high or low cost of bailing out banks, as in **?**. In this paper, we take the latter approach in the context of CoCos.

The regulator is interested in the total utility achieved in the system, irrespective of the distribution of the gains or losses over the various agents. One can see that the CoCo writedown is only a redistribution of wealth: conversion increases the equity value of the bank but deals an equivalent loss to the CoCo holders. As it does nothing to change the social value of the assets, the regulator is unaffected by conversion for its own sake.

However, conversion has consequences. Since it is publicly observable, it makes other agents aware of an adverse change in the system. On the other hand, since conversion increases the bank's skin in the game, it may lead to socially better choices. But holding the bank's choice constant, the regulator prefers forbearance, because forbearance does not transmit bad news to the outside agents. We represent the costs of conversion by χ. This cost is similar to those assumed by **?** and

?. For the moment, the costs are exogenous, but in a later section, we endogenize χ by linking it to depositor runs. Table 1 illustrates the difference in regulator payoffs under conversion and forbearance.

Table 1: Regulator Payoffs at $t = 2$: Benchmark

Regulator Payoff	Conversion	Forbearance
Safe asset	$R_s - \chi$	R_s
Risky asset, Gamble	$sR_r - \chi$	sR_r
Risky asset, Liquidate	$s^\lambda R_r - \chi$	$s^\lambda R_r$

The regulator has to balance the costs of conversion and the benefits of conversion if the latter induces the bank to choose liquidation over gambling. Therefore, the relevant comparison is between the (Conversion, Liquidate) and the (Forbearance, Gamble) cases in Table 1. That is,

$$s^\lambda R_r - \chi \;>\; sR_r$$

$$\chi \;<\; q\left(\lambda - p\right)R_r = \bar{\chi}, \tag{14}$$

where $\bar{\chi}$ is the threshold level of conversion costs. Whenever (14) holds, the regulator will choose conversion over forbearance, if the LIC holds after conversion.

We have determined the conditions under which a regulator and a bank would make their $t = 1$ decisions. Consider now their interactions. Table 2 shows the bank's payoffs under its two possible strategies as a function of the regulator's action. In all situations, holding the bank's choice constant, the bank's liabilities under forbearance is always rC more than under conversion.

Table 2: Bank Payoffs at $t = 2$: Benchmark

Bank Payoff	Conversion	Forbearance
Safe asset	$R_s - rD$	$R_s - r(D + C)$
Risky asset, Gamble	$s\left(R_r - rD\right)$	$s\left(R_r - r(D + C)\right)$
Risky asset, Liquidate	$s^\lambda R_r - rD$	$s^\lambda R_r - r\left(D + C\right)$

Reading from Table 2, holding the regulator's choice constant, the bank payoffs under gambling and liquidation reflects the LIC in (11), only for specific values of liability B. If the regulator chooses to forbear, the bank's outstanding liability remains $r(D + C)$. But it the regulator chooses to convert, the outstanding liability is reduced to rD. The benefit of conversion is that it changes the relevant bank payoffs from the LIC (same regulator decision) to a different one: $s^\lambda R_r - rD$

against $s\left(R_r - r(D+C)\right)$. By defining the debt threshold in terms of equity, we are able to quickly assess whether conversion changes the bank's $t=1$ decision or not.

Let E_{forb} denote the bank's expected equity level under forbearance. The bank only chooses to liquidate rather than to gamble whenever the bank's equity level exceeds the threshold defined in (13):

$$E_{forb} = sR_r - r\left(D+C\right) \geq E^*. \tag{15}$$

If the regulator chooses conversion, then the bank's liabilities would decrease from $r\left(D+C\right)$ to rD, since rC is written off. Let E_{conv} denote the bank's expected equity level after conversion. The bank would choose liquidation over gambling if

$$E_{conv} = sR_r - rD \geq E^*. \tag{16}$$

The regulator only prefers to convert if it makes the bank choose liquidation. So when is conversion enough to make the bank's new equity exceed the threshold? If the bank was not able to satisfy (15), it may still be able to satisfy (16), provided that the shortfall is less than rC. Table 3 summarizes the different cases that a bank's capital structure may fall into, and the best response of the bank and the regulator given the cases.

Table 3: Bank and Regulator Interactions: Benchmark

Case	Situation	Action Chosen by Bank under		Regulator's Choice
		Forbearance	Conversion	
I	$E_{conv} > E_{forb} > E^*$	Liquidate	Liquidate	Forbearance
II	$E_{conv} > E^* > E_{forb}$	Gamble	Liquidate	Conversion, if $\chi < \bar{\chi}$
III	$E^* > E_{conv} > E_{forb}$	Gamble	Gamble	Forbearance

Case I is when $E_{conv} > E_{forb} > E^*$, or when the bank's skin in the game already exceeds the threshold E^*. Note that conversion only increases the bank's skin in the game. Since the bank already satisfies the LIC without conversion, it will also satisfy the LIC with conversion, so in both cases, the bank will choose to liquidate. Because the conversion changes nothing for the bank, but incurs a cost to the regulator, the regulator will therefore forbear.

Case II is when $E_{conv} > E^* > E_{forb}$, whihc implies that the bank's skin in the game will only exceed the threshold E^* upon conversion. Therefore, conversion makes a difference.

Case III is when $E^* > E_{conv} > E_{forb}$, i.e when the bank's skin in the game falls short even after conversion . As a result, conversion also does nothing: the bank will choose to gamble even if the regulator converts the CoCos. Therefore, the regulator will also forbear in this case.

Proposition 4.1 summarizes the results.

Proposition 1. *Given levels of deposits D and CoCos C, and given that the bank has chosen risky assets at $t = 0$, if the bank's equity level is within $rC-$distance of the liquidation incentive constraint, the regulator is able to force the bank to choose liquidation over gambling, by choosing conversion. However, the regulator will only choose conversion if the costs are sufficiently low.*

4.2 Arrival of adverse information at $t = 1$

The arrival of adverse information occurs at $t = 1$. However, these events are completely unanticipated at $t = 0$, that is, we model them as zero-probability events. The new information takes the form of revised parameter values for the risky asset. In our setup, we consider two types of shocks: a shock on the fraction of bad loans q, and a shock on the probability of obtaining returns of the bad loans p . One may interpret the shock on q as an aggregate shock that increases the volume of nonperforming loans, as in **?**. On the other hand, the p shock may be interpreted as a shock that only affects the existing nonperforming loans - that is, it makes their recovery more unlikely.[11] We assume that both are large enough to cause the equity ratio to fall below the trigger τ. Naturally, this implies that if the shocks are small, the regulator would forbear on conversion. These shocks alter both the bank's liquidation incentive constraint, and the regulator's threshold costs of conversion. We discuss each type of shock separately.

4.2.1 A q-shock: an increase in the proportion of bad loans within the risky asset class

We first consider a shock to the proportion of bad loans within the risky asset class That is, suppose at $t = 1$, the proportion of bad loans q increase to some $q' > q$, holding the probability of obtaining the return from the bad loans p constant. The effect of this is that the composite probability s of

---

[11]The p shock may be interpreted as an industry-specific or a demand-side shock shock that decreases the likelihood of obtaining returns from investments in a certain industry. An example is unexpected regulatory changes that that negatively affect the cash flow of a firm in a particular industry.

obtaining the outlier return R_r for the risky portfolio decreases. For ease of exposition, relabel by $s(q)$ the $s = 1 - q + qp$ defined in (2). We have

$$\frac{\partial s(q)}{\partial q} = -(1-p) < 0. \tag{17}$$

Denote the revised composite probability by $s(q')$: $s(q') = 1 - q' + q'p$. Consider a shock that is large enough to cause the equity ratio to fall below the trigger level τ. That is,

$$\frac{s(q)R_r - r(D+C)}{s(q)R_r} \geq \tau > \frac{s(q')R_r - r(D+C)}{s(q')R_r}. \tag{18}$$

The shock to q also affects the bank's liquidation payoffs. The liquidation value λ is larger than p, but the liquidation value interacts with the proportion of bad loans q' in the risky portfolio. For ease of exposition, relabel by $s^\lambda(q)$ the recovery value $s^\lambda = 1 - q + q\lambda$ for the full risky asset defined in (9). We have

$$\frac{\partial s^\lambda(q)}{\partial q} = -(1-\lambda) < 0, \tag{19}$$

which leads to the recovery value of the risky asset (given that the liquidation strategy is chosen), given a shock to q as

$$(1-q')R_r + q'\lambda R_r = s^\lambda(q')R_r. \tag{20}$$

Therefore, the liquidation incentive constraint changes after the shock to q at $t = 1$. The bank now considers the following inequality for some outstanding liability B:

$$s^\lambda(q')R_r - B \geq s(q')(R_r - B), \tag{21}$$

which leads to

$$B \leq \left(\frac{\lambda - p}{1 - p}\right)R_r = B^*, \tag{22}$$

the same threshold that was obtained in the benchmark case. Intuitively, this is because the shock to q does not make gambling for resurrection any less attractive than in the benchmark case. If it did, it would show up in both the difference between λ and p, as well as in the per-loan Merton put

benefit $(1 - p)$. One can see this upon closer inspection of the LIC. We can rewrite (21) as follows:

$$
\begin{aligned}
s^\lambda \left(q'\right) R_r - B &\geq s\left(q'\right) R_r - B + \left[1 - s\left(q'\right)\right] B \\
q'\lambda R_r &\geq q'pR_r + q'\left[1 - p\right] B.
\end{aligned}
\tag{23}
$$

Note that (23) shows that the simplified form of (21) has elements which all contain the factor q'. This means that even if on aggregate, gambling for resurrection becomes more attractive, the increase in the Merton put implied by the bank's limited liability exactly offsets the attractiveness of gambling for resurrection.

As before, (22) may be transformed in terms of equity by adding the bank's expected returns. But even if the composite probability s falls to some $s\left(q'\right) < s$, it affects both sides of (22) in the same way. In particular, if we let $q' = q + \nu$, we have $s\left(q'\right) = s - \nu\left(1 - p\right)$ and the LIC (under regulatory forbearance) becomes

$$
\left[s - \nu\left(1 - p\right)\right] R_r - B > \left[s - \nu\left(1 - p\right)\right] R_r - B^*.
\tag{24}
$$

But this simplifies to

$$
sR_r - B > sR_r - B^* \equiv E^*,
\tag{25}
$$

which is identical to (13) that we obtained in the benchmark case. This means that a shock to the quantity of bad loans, holding the probability constant does not change the bank's threshold governing the choice of liquidation over gambling, relative to the benchmark case. The expected value of the asset falls as well, but it affects both sides of (22) in the same way. Therefore, the only thing that can possibly change a bank's incentive is the conversion of the CoCo, as in the benchmark case.

While the bank is not affected by the increase in q, the regulator is. This is because while the increase in q affects both the difference between λ and p, and the Merton put in the same way and therefore cancel out, the regulator has no such mechanism. Instead, the regulator faces the social cost of a higher number of loan failures. As a result, the regulator's threshold cost of conversion is also affected. As the shock to q changes both the composite probability $s\left(q\right)$ to $s\left(q'\right)$, and the recovery value $s^\lambda\left(q\right)$ to $s^\lambda\left(q'\right)$, the regulator's payoff functions are also altered. Table 4 shows the

payoffs after the arrival of new information.

Table 4: Regulator Payoffs at $t = 2$: q-shock

Regulator Payoff	Conversion	Forbearance
Safe asset	$R_s - \chi$	R_s
Risky asset, Gamble	$s(q') R_r - \chi$	$s(q') R_r$
Risky asset, Liquidate	$s^\lambda(q') R_r - \chi$	$s^\lambda(q') R_r$

The regulator will only choose conversion whenever

$$s^\lambda(q') R_r - \chi > s(q') R_r$$

$$\chi < q'(\lambda - p) R_r = \bar{\chi}_q \tag{26}$$

Since $q' > q$, $\overline{\chi_q} > \bar{\chi}$. Therefore, the threshold of a regulator is higher after a bad q-shock than without. This is because a q-shock means that a larger amount of loans could go bad, meaning that there are more opportunity losses for the system. Lemma 2 summarizes the results.

Lemma 2. *Given χ, a negative shock to q makes the regulator less wary of conversion because the social cost of gambling for resurrection goes up (applies to more loans).*

Because we were able to express the bank's expected equity levels under a q-shock, in terms of those in the benchmark case, we may use the same notation as in the benchmark case. The analysis here is structurally similar to that of the benchmark case, with the exception that the regulator's threshold is higher here. Table 5 summarizes the results.

Table 5: Bank and Regulator Interactions: q-shock

Case	Situation	Action Chosen by Bank under		Regulator's Choice
		Forbearance	Conversion	
I	$E_{conv} > E_{forb} > E^*$	Liquidate	Liquidate	Forbearance
II	$E_{conv} > E^* > E_{forb}$	Gamble	Liquidate	Conversion, if $\chi < \bar{\chi}_q$
III	$E^* > E_{conv} > E_{forb}$	Gamble	Gamble	Forbearance

Proposition 3. *An increase in q does not affect the bank's decision rules such that the bank's decisions under a q shock are the same as under the benchmark case. However, a shock to q raises social costs, and makes it "easier" to convince the regulator to convert the CoCos: the range of values for which the regulator chooses forbearance is smaller.*

4.2.2 A p-shock: a decrease in the probability of obtaining the return of the bad loans within the risky asset class

Consider now a shock in the probability of obtaining the return from the bad loan, holding the proportion of bad loans constant. That is, at $t = 1$, suppose p falls to some $p' < p$, holding q constant. The effect of this is that the composite probability s of obtaining return R_r for the risky portfolio goes down. For ease of exposition, relabel by $s(p)$ the $s = 1 - q + qp$ defined in (2). We have

$$\frac{\partial s(p)}{\partial p} = q > 0. \tag{27}$$

Denote the revised compound probability by $s(p')$: $s(p') = 1 - q + qp'$. Like the shock to q, we assume that the shock to p is large enough to cause the equity ratio to fall below the trigger level τ. That is,

$$\frac{s(p) R_r - r(D + C)}{s(p) R_r} \geq \tau > \frac{s(p') R_r - r(D + C)}{s(p') R_r}. \tag{28}$$

The shock to p does not affect the bank's liquidation payoff s^λ at all. However, since the shock increases the gap between the liquidation value λ and the probability of obtaining positive returns for a given proportion q of bad loans, the p-shock makes gambling for resurrection less attractive compared to the benchmark case. The shock to p not only affects the relative gain of liquidation over gambling, it also affects the Merton put from limited liability. The effects do not cancel out, unlike that of the q shock case. For outstanding liability B, the LIC that the bank faces in order to choose liquidation over gambling, for a given q, becomes

$$s^\lambda R_r - B \geq s(p')(R_r - B) \tag{29}$$

which further simplifies to

$$B \leq \left(\frac{\lambda - p'}{1 - p'}\right) R_r = B_p^*, \tag{30}$$

where B_p^* is the threshold level of liabilities that the bank must exceed for liquidation to be chosen. (30) is similar to (11) but with p' instead of p. Because the derivative of B^* with respect to p is negative, a drop in p leads to an increase in B^*, and so $B_p^* > B^*$. This means that a shock to p may lead banks to choose liquidation, without having to be nudged by a CoCo conversion, because

even if $B > B^*$, it may be the case that $B < B_p^*$. Of course, this also means that the corresponding equity threshold goes down.

Letting δ be the size of the shock to p, we may write $p' = p - \delta$, and write B_p^* in terms of B^* as follows:

$$
\begin{aligned}
B_p^* &= \left(\frac{\lambda - p}{1 - p}\right) R_r + \left(\frac{\delta R_r}{1 - p + \delta}\right)\left(\frac{1 - \lambda}{1 - p}\right) \\
B_p^* &= B^* + \Delta,
\end{aligned} \tag{31}
$$

such that (30) may be written in terms that appear in the benchmark case. We then have

$$
B \leq B^* + \Delta, \tag{32}
$$

which may be transformed in terms of equity by adding the bank's expected returns $s(p') R_r$ to both sides. But even if the composite probability $s(p)$ falls to some $s(p') < s(p)$, it affects both sides of (30) in the same way. More specifically, if we let $p' = p - \delta$, we have $s(p') = s(p) - q\delta$ and the LIC (under regulatory forbearance) becomes, for outstanding liability B,

$$
(s(p) - q\delta) R_r - B \geq (s(p) - q\delta) R_r - (B^* + \Delta). \tag{33}
$$

But this simplifies to

$$
s(p) R_r - B \geq s(p) R_r - (B^* + \Delta) = E^* - \Delta.
$$

That is, the bank needs less skin in the game with a p-shock relative to the benchmark case in order to choose liquidation over gambling. For the p-shock, the fact that the equity threshold E^* is lower by Δ means that if the liquidation incentive constraint was met in the benchmark case, it would definitely be met in the p-shock case.

Lemma 4. *Ceteris paribus, a p-shock increases the range of outcomes over which the bank will choose liquidation over gambling.*

This means that the bank acts in a more conservative manner when faced with a p shock, as opposed to a q shock.

The regulator's conversion cost threshold is altered whenever there is a shock to p. The shock

to p changes the composite probability $s(p)$ to $s(p')$, but not the recovery value s^λ. Table 6 shows the payoffs to the regulator after a shock to p.

Table 6: Regulator Payoffs at $t = 2$: p-shock

Regulator Payoff	Conversion	Forbearance
Safe asset	$R_s - \chi$	R_s
Risky asset, Gamble	$s(p') R_r - \chi$	$s(p') R_r - rD$
Risky asset, Liquidate	$s^\lambda R_r - \chi$	$s^\lambda R_r$

From this table, we can see that the regulator will only choose conversion whenever

$$s^\lambda R_r - \chi > s(p) R_r$$
$$\chi < q(\lambda - p') R_r = \bar{\chi}_p. \tag{34}$$

This is structurally similar to the benchmark case, but with $p' < p$, the threshold also rises. The regulator has higher tolerance for conversion when there is a shock to p because once again the social cost of allowing gambling for resurrection has gone up, and the forbearance region shrinks.

Lemma 5. *Given cost of conversion χ, a shock to p makes regulators less wary of conversion because of the higher social cost that comes from the shock.*

Because we were able to simplify the bank's expected equity levels under a p-shock, in terms of those in the benchmark case, the analysis follows exactly as in the benchmark case, with the exception that the bank's equity threshold is lower by Δ. Table 7 and Proposition 4.6 summarizes the results.

Table 7: Bank and Regulator Interactions: p-shock

Case	Situation	Action Chosen by Bank under		Regulator's Choice
		Forbearance	Conversion	
I	$E_{conv} > E_{forb} > E^* - \Delta$	Liquidate	Liquidate	Forbearance
II	$E_{conv} > E^* - \Delta > E_{forb}$	Gamble	Liquidate	Conversion, if $\chi < \bar{\chi}_p$
III	$E^* - \Delta > E_{conv} > E_{forb}$	Gamble	Gamble	Forbearance

Proposition 6. *A shock to p leads to a smaller equity threshold for the bank relative to the benchmark case, and thus, increases the range where the bank would choose liquidation over gambling. Structurally, all the results of the benchmark case do not change. However, the range of values for which the regulator chooses forbearance is smaller.*

We have made the above analysis without specifying the size of the p- shock. However, we can let the size of the shock vary as well. Consider again Table 7. Given the amount of CoCos rC, if the bank's capital structure falls within Cases I and II, an increase in the shock can only encourage the bank to choose liquidation over gambling. This is because the threshold $E^* - \Delta$ becomes smaller as the shock increases. If the bank's capital structure falls under Case III, the shock may move the bank from Case III to Case II or even Case I. In this narrow sense, the shock may be beneficial to the regulator in that it allows the conversion to be useful in changing the decision of the bank, given a particular amount of CoCos. Of course if the CoCos are too few, then a large shock would not change anything.

Figure 3 illustrates how the bank moves from Cases III to I as the shock Δ changes.

Figure 3: Bank's Equity Levels for Various Shock Sizes
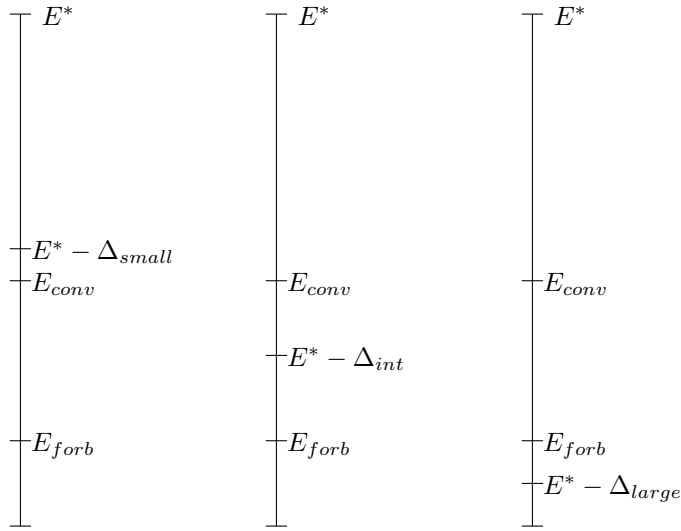
The image labeled "small shock" illustrates Case III of Table 7. The crisis has caused the threshold to fall to some $E^* - \Delta_{small}$, but the bank's equity after conversion is still smaller than the threshold, leading the bank to choose to gamble even if the regulator had chosen conversion. This illustrates the futility of conversion during a small shock, provided that the bank is in Case III to begin with. The image labeled "intermediate shock" illustrates the bank moving from Case III to Case II of Table 7. In this case, the threshold has fallen to $E^* - \Delta_{int}$. While $E_{forb} < E^* - \Delta_{int}$, a conversion leads to $E_{conv} > E^* - \Delta_{int}$. In this case, the regulator's decision to convert the

CoCos leads the bank to choose liquidation over gambling. Finally, the image labeled "large shock" illustrates the bank moving from Case III to Case I of Table (7). Consider the benchmark case. Even if the bank chose gambling in the benchmark case, the shock is large enough to cause the threshold to fall down to $E^* - \Delta_{large}$. This means that even without a conversion, the bank is already incentivized to choose liquidation. As such, conversion is also useless in this case, because the bank already chooses the right decision under forbearance.

Proposition 7. *Provided that the LIC was not satisfied in the benchmark case, the regulator will only convert CoCos if the shocks are in the intermediate range and if the cost of conversion is not too high. CoCos will not be converted in the event of either a small shock or a large one: small shocks are not enough of a deterrent from gambling, and large shocks automatically cause the LIC to hold.*

This result has significant policy implications, as it is precisely in the event of large shocks that CoCos are considered useful for the financial system. In the presence of large shocks, the banks will decide on liquidation over gambling for resurrection even without regulatory intervention. This is precisely why the regulator will tend to forbear, as she would like to avoid the conversion costs. However, her forbearance makes the financial system weaker than it should be, as it leaves the banks with less equity than it otherwise might have, as E_{forb} is always smaller than E_{conv}.

5   Endogenizing the cost faced by a regulator

There are many reasons why the regulator would face conversion costs. One of them is the incompleteness of deposit insurance. In particular, wholesale deposits are not typically covered by deposit insurance, or are only marginally covered. Until now, we have abstracted from the issue of depositor behavior, focusing instead on the interaction between the regulator and the bank, and assuming an exogenous cost of conversion χ. In this section, we endogenize the regulator's χ by letting her conversion decision affect the threshold beliefs of the depositors. We assume that depositors have prior beliefs regarding the bank's asset choice such that their participation constraint of depositors is satisfied. The belief level that causes the depositors' participation constraint to bind may be interpreted as the probability of a bank run. That is, if the threshold belief is not satisfied, the depositors would run. We model depositors as uninformed in this section: they are only aware of

the promised return r, but unaware of the asset that the bank had chosen at $t = 0$. Moreover, the depositors are unaware of the composite probability of obtaining a positive return from the risky asset. All they have are beliefs about these parameters. But as conversion is an observable event, and occurs only if the bank had invested in a risky asset, the conversion shifts the beliefs of the depositors. As a result, the probability of a bank run increases. The increase in the run probability after a conversion is a key component of the regulator's endogenous cost of conversion.

5.1 Depositors' beliefs

As mentioned in Section 3, the depositors are risk neutral. They will invest in a bank only if they at least break even in expectation. For simplicity, let the beliefs of all the depositors be the same, rather than being distributed along some interval.[12] The depositors are relatively uninformed - they know neither the type of asset the bank has invested in at $t = 0$, nor the probability of obtaining the returns of the risky asset s. Instead, they have beliefs on these two dimensions.

Let the depositors' belief that the bank invested in the safe asset be some $\theta \in [0, 1]$, such that the belief that the bank invested in the risky portfolio is $1 - \theta$. Safe assets ensure that $r(D + C)$ will be paid, which means that each of the depositors will obtain r. Risky assets only pay out r with some probability $s = 1 - q + pq$, but we assume that the depositors do not know s. They do have a belief about the probability of obtaining returns from the risky asset, which is α.[13] The depositors can only perform this calculation if they hold beliefs about the bank's initial asset choice, and the probability of obtaining the high return in the risky asset. Therefore, there are are two beliefs that the depositors must hold. In short, the depositors have a composite belief: about the bank's investment in a safe or risky asset $(\theta, 1 - \theta)$, along with a belief α on how likely the risky asset pays off. For runs not to happen, the depositors' α must satisfy (35):

$$\theta r + (1 - \theta)(\alpha r + (1 - \alpha) 0) \geq 1$$
$$\alpha \geq \frac{1}{r}\left(\frac{1 - \theta r}{1 - \theta}\right) = \bar{\alpha}, \tag{35}$$

where $\bar{\alpha}$ is the threshold belief of the depositor for which a run does not occur. Thus, the threshold

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[12]In principle, depositors may have beliefs that are drawn from a distribution. In particular, **?** have used this to model bank runs.

[13]The modelling here is similar to **?**, except that instead of having a prior on whether the bank is good or bad, the prior is on whether the bank has invested in a safe or risky asset.

belief of the depositors is a function of their belief regarding the bank's $t = 0$ investment. We assume that in the absence of any information, the depositors' α is exactly at $\bar{\alpha}$. Note as well that

$$\frac{\partial \bar{\alpha}}{\partial \theta} = -\frac{(r-1)}{r(1-\theta)^2} < 0, \tag{36}$$

which indicates that the higher the belief that the bank has invested in the safe asset, the lower $\bar{\alpha}$ will be. However, in our setup, the signals can only lower θ, rather than raise it. This is because by construction, conversion will only occur if the bank has invested in the risky asset at $t = 0$. So depositors observing the conversion would interpret it adversely, and will therefore lead to an increase in $\bar{\alpha}$ to some $\bar{\alpha}'$. Thus, assuming that $\alpha = \bar{\alpha}$ implies that $\alpha < \bar{\alpha}'$. At the same time, even if the regulator knows that the bank has invested in a risky asset, the regulator would not convert the CoCo unless she comes across adverse information about the bank's likelihood of obtaining positive returns. As such, forbearance is never informative about the bank's asset choice.

Thus, if the regulator does not convert the CoCo, the threshold belief stays at $\bar{\alpha}$ for a given θ. However, when the regulator converts CoCos, it is certain that the asset is a risky one. So the only time that the depositors can update their beliefs is when they observe a CoCo conversion. The belief that the bank has chosen a safe asset θ must be updated to 0, while the belief that the bank invested in the risky portfolio $1 - \theta$ must be updated to 1.[14] Therefore, the above equation simplifies to

$$\begin{aligned}
(\alpha r + (1 - \alpha) \, 0) &\geq 1 \\
\alpha &\geq \frac{1}{r} = \bar{\alpha}'. \tag{37}
\end{aligned}$$

Since $\frac{\partial \bar{\alpha}}{\partial \theta} < 0$ from (35), it must be that $\bar{\alpha}' > \bar{\alpha}$. Therefore, if conversion is the only signal that depositors can obtain to update their beliefs, then a conversion definitely raises the threshold belief, as conversion would never happen with a safe asset. This means that the marginal probability of a bank run caused by a conversion is $\bar{\alpha}' - \bar{\alpha}$. This is summarized in the proposition below.

Proposition 8. *For any belief that depositors hold regarding the bank's initial choice of assets, a conversion updates those beliefs in such a way that the belief that the bank holds the risky asset is*

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[14]The updating mechanism here is similar to **?** where they model the updating of the depositors' perception of the regulator's reputation based on information about the bank's performance.

1. This leads to the increase in the threshold belief for runs not to occur from α to $\bar{\alpha}' > \bar{\alpha}$.

In this section, we have only considered full conversions. In principle, partial conversions may be observed for small shocks. For whatever belief an individual attaches to the safe asset θ, it will be at least lower in the event of a conversion, if not going completely to 0. This follows from (36), which means that the threshold for bank runs will still increase even with nonextreme beliefs about the safe and risky asset, as long as the belief regarding the safe asset goes down.

It is important to note that the conversion does not affect claims between depositors and CoCo holders. This is because depositors have seniority over all the other creditors. Conversion is merely a signal about the assets of the bank, and this is reflected in (35).

5.2 Taking depositors' beliefs into account

By design, conversion (or forbearance) precedes both the depositors' decision to run as well as the bank's second decision point. This implies that by the time that bank has to choose between gambling and liquidation, the bank faces either run probability $\bar{\alpha}'$ if the regulator decided on conversion, or $\bar{\alpha}$ if the regulator decided on forbearance. Therefore, the bank's choice between gambling and liquidation takes the run probabilities as given upon the regulator's decision. That is, when the regulator decides upon either conversion or forbearance, the bank faces the same probability of a run: upon conversion, it is $\bar{\alpha}'$ under both gambling and liquidation, which means that there is a $1 - \bar{\alpha}'$ probability of not being run on. Similarly, upon forbearance, the probability of a bank run is $\bar{\alpha}$ under both gambling and liquidation, which means that there is a $1 - \bar{\alpha}$ probability of not being run on. The bank survives conditional on a run not occuring, and receives nothing upon a run. Table 8 illustrates the bank payoffs for each choice given the regulator's decision, while taking the run probabilities into account.

Table 8: Bank Payoffs Accounting for Runs

Bank Payoff	Conversion	Forbearance
Safe asset	$(1 - \bar{\alpha}') [R_s - rD]$	$(1 - \bar{\alpha}) [R_s - r(D + C)]$
Risky asset, Gamble	$(1 - \bar{\alpha}') [s (R_r - rD)]$	$(1 - \bar{\alpha}) [s (R_r - r(D + C))]$
Risky asset, Liquidate	$(1 - \bar{\alpha}') [s^\lambda R_r - rD]$	$(1 - \bar{\alpha}) [s^\lambda R_r - r (D + C)]$

If the bank takes the probability of runs into account, their decision between gambling and liquidation does not change relative to the case where we abstracted from runs. This is because the

probability of surviving a run $(1 - \bar{\alpha})$ or $(1 - \bar{\alpha}')$ is a constant factor that affects the payoffs from gambling and liquidation in exactly the same way. As such, banks are not bothered by an increase in the threshold belief due to the conversion.

For the regulator, it is not as straightforward. In the event of a bank run without deposit insurance, the depositors will recover their funds at $t = 1$ but doing so interrupts the investment process. This means that when a run happens, the economy loses the potential profit of the expected return net of the initial investment of 1. To a welfare-maximizing regulator, this is an opportunity loss. The bank does not face this though, as it has limited liability, it calculates its gains conditional on surviving.[15] Therefore, if we were to take this opportunity loss into account, the payoffs to the regulator upon conversion will always be less than the payoffs upon forbearance, if only because of the increase in the probability of bank runs. Table 9 shows the regulator payoffs if the threshold beliefs of depositors are taken into account:

Table 9: Regulator Payoffs Accounting for Runs

Regulator Payoff	Conversion	Forbearance
Safe asset	$(1 - \bar{\alpha}') R_s + \bar{\alpha}' (R_s - 1)$	$(1 - \bar{\alpha}) R_s + \bar{\alpha} (R_s - 1)$
Risky asset, Gamble	$(1 - \bar{\alpha}') s R_r + \bar{\alpha}' (s R_r - 1)$	$(1 - \bar{\alpha}) s R_r + \bar{\alpha} (s R_r - 1)$
Risky asset, Liquidate	$(1 - \bar{\alpha}') s^\lambda R_r + \bar{\alpha}' (s^\lambda R_r - 1)$	$(1 - \bar{\alpha}') s^\lambda R_r + \bar{\alpha}' (s^\lambda R_r - 1)$

We may write the forbearance payoffs in terms of the conversion payoffs for all actions of the bank. We illustrate it for the safe asset, but it also works for the others. The difference between the payoffs of forbearance and conversion for the safe asset may be written as

$$\underbrace{[(1 - \bar{\alpha}) R_s + \bar{\alpha} (R_s - 1)]}_{forbearance} - \underbrace{[(1 - \bar{\alpha}') R_s + \alpha' (R_s - 1)]}_{conversion} = \bar{\alpha}' - \bar{\alpha} \tag{38}$$

Thus, letting $\chi = \bar{\alpha}' - \bar{\alpha}$, Table 9 may be simplified to Table 10.

Table 10: Regulator Payoffs Accounting for Runs: Simplified

Regulator Payoff	Conversion	Forbearance
Safe asset	$(1 - \bar{\alpha}) R_s + \bar{\alpha} (R_s - 1) - \chi$	$(1 - \bar{\alpha}) R_s + \bar{\alpha} (R_s - 1)$
Risky asset, Gamble	$(1 - \bar{\alpha}) s R_r + \bar{\alpha} (s R_r - 1) - \chi$	$(1 - \bar{\alpha}) s R_r + \bar{\alpha} (s R_r - 1)$
Risky asset, Liquidate	$(1 - \bar{\alpha}) s^\lambda R_r + \bar{\alpha} (s^\lambda R_r - 1) - \chi$	$(1 - \bar{\alpha}) s^\lambda R_r + \bar{\alpha} (s^\lambda R_r - 1)$

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[15]? refer to this phenomenon as the "internalization effect" in the context of capital regulation, where increased regulation decreases the marginal return of the bank, as higher requirements increase the bank's skin in the game, so it internalizes the downside risk.

But by rearranging terms, we arrive at Table 11, which, upon closer inspection, is essentially the same as Table 1 but shifted up by a constant $\bar{\alpha}$.

Table 11: Regulator Payoffs Accounting for Runs: Even More Simplified

Regulator Payoff	Conversion	Forbearance
Safe asset	$R_s + \bar{\alpha} - \chi$	$R_s + \bar{\alpha}$
Risky asset, Gamble	$sR_r + \bar{\alpha} - \chi$	$sR_r + \bar{\alpha}$
Risky asset, Liquidate	$s^\lambda R_r + \bar{\alpha} - \chi$	$s^\lambda R_r + \bar{\alpha}$

This endogenizes the cost of conversion as the increase in the probability of bank runs.

6 $t = 0$ decisions when the regulator type is unknown

A bank can choose any asset at $t = 0$ it wishes as long as it complies with regulation. However, its choice at $t = 0$ ultimately depends on what actions it expects the regulator would do at $t = 1$. We have illustrated these in the previous sections, for the benchmark case, and for two shock cases.

After a negative shock, the choice made may no longer be regulation-compliant. Ideally, this is when CoCos are useful. Whether they actually turn out to be useful depends on the type of regulator. A regulator may face high costs of conversion in times of greater financial fragility, as the beliefs of the depositors may not reach the threshold necessary for runs not to occur. As a result, a regulator that faces a high cost of conversion will forbear on tough decisions, while a regulator that faces a lower cost of conversion will cause the conversion to happen.

If the type of regulator is known, then it is easy for the bank to make its $t = 0$ decision, as it can foresee what the regulator does in any situation. But if it is unknown, the bank must hold some beliefs regarding the type of regulator it is dealing with. In this section we will examine the more realistic (and interesting) case where the bank does not know the type of the regulator. This will also enable us to determine under which conditions does the game have a solution at $t = 0$. For this, we set up an extended game tree as shown in Figure 4.
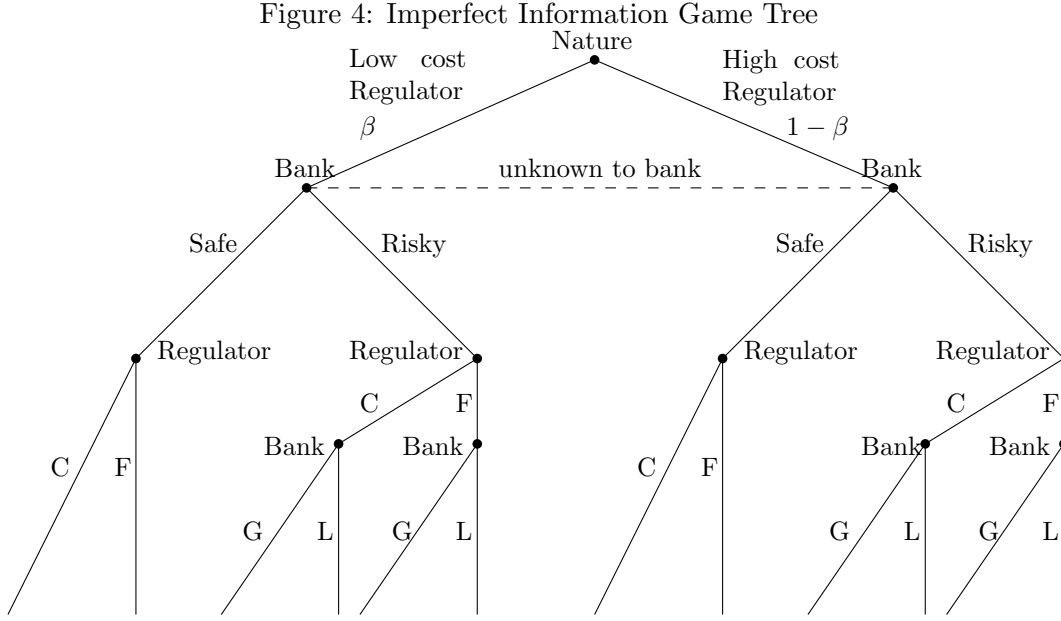
Figure 4: Imperfect Information Game Tree

Figure 4 is composed of two copies of Figure 2 connected by a Nature node that determines the type of regulator that the bank is dealing with, and C, F, G, L stand for Conversion, Forbearance, Gambling, and Liquidation, respectively. On the Low Nature branch, the regulator's cost of conversion is low enough to lead her to conversion, while on the High Nature branch, the cost of conversion is high enough to always lead the regulator to choose forbearance. As the bank does not know the type of regulator it is dealing with, it assigns a belief β that the regulator has a low cost of conversion, and $1 - \beta$ that the regulator has a high cost of conversion. We first consider the decisions made by the bank under perfect information - that is, if the bank knows the type of regulator it is dealing with. We then characterize the beliefs that the bank must have in order to rationalize its decisions in the imperfect information setting.

6.1 Linking the endogenous cost of conversion χ to the existence of a high cost and a low cost regulator

In the previous section, we have endogenized the cost of conversion χ by linking it to the marginal probability of a bank run caused by an updating of depositors' beliefs. The endogenous cost of conversion is not inconsistent with the concept of a high-cost and a low-cost regulator: we have only defined the cost of conversion for one bank. However, if one were interested in financial fragility and network effects, one can easily model the same by extending the conversion costs to some n

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number of banks.

Let us assume that there are n banks which are identical in capital structure, but not necessarily in investment. The important thing is that the depositors from the n banks all behave in the same way - that is, they are relatively uninformed about the type of asset the bank has invested in at $t = 0$, and the probability of obtaining the returns of the risky asset s. Instead, they have beliefs on these two dimensions, as described in Section 5.

Given that conversion is publicly observable, it is conceivable that depositors of all the n banks in a network increase their threshold beliefs from $\bar{\alpha}$ to $\bar{\alpha}'$, leading to the conversion cost $\chi = \bar{\alpha}' - \bar{\alpha}$. If there are n banks, then such a contagion mechanism[16] will imply that the total effect in the network would be $n\chi$. What drives the difference between the high and the low cost regulator is the degree of asset correlatedness that is faced by the regulator. Let the asset correlatedness faced by the high cost regulator be ρ_H (and let ρ_L be the corresponding one for the low cost regulator, where of course, $\rho_H > \rho_L$). Then, we can define the cost faced by the high cost regulator as $\chi_H = n\rho_H\chi$, and the cost faced by the low cost regulator as $\chi_L = n\rho_L\chi$.

6.2 What drives the bank's decision to choose the safe asset over the risky one?

CoCos are only effective moral hazard deterrents at $t = 1$ if they allow the liquidation incentive constraint to be met. There are two instances when they do not make a difference: if the LIC is met even without conversion (in which case the regulator forbears and the bank liquidates), and if the LIC is not met even with conversion (in which case the regulator forbears and the bank gambles). Given the $t = 1$ decisions, it is also interesting to see whether CoCos deter banks from choosing the risky asset at $t = 0$. In order to do so, we must take a closer look at the assumptions regarding the returns. Because this is a $t = 0$ assessment, we do not consider the shocks to either p or q, because we have assumed that they are unexpected at $t = 0$. That is, neither the regulator nor the bank know that the shocks to either p or q are forthcoming. Instead, they assume that p and q at $t = 0$ are the true distributional parameters. (4) describes the relative returns, reproduced below

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[16]**?** considers a similar contagion mechanism.

for convenience.

$$\underbrace{s\left(R_r - r\left(D + C\right)\right)}_{private\ return\ risky\ asset} > \underbrace{R_s - r\left(D + C\right)}_{return\ safe\ asset} > \underbrace{sR_r - r\left(D + C\right)}_{social\ return\ risky\ asset} \tag{39}$$

In the previous sections, we have not made any assumption about the size of the safe asset net return relative to that of the liquidated risky asset. We remedy that here. Consider again the risky portfolio. A fraction $1 - q$ yields R_r with certainty, and a fraction q yields R_r with probability p. Therefore, only the fraction q of bad loans will be liquidated. We have denoted the recovery value from liquidating this portfolio as $s^\lambda R_r$.

We are now in a position to compare expected returns. First, note that given the assumption of risk neutrality of the bank, it does not make sense to assume that $s^\lambda R_r > R_s$, because if that were the case, no one would invest in safe assets in the first place. It would be more profitable to invest in the risky portfolio and then liquidate it with certain yield λR_r per unit of bad loan q. Therefore, for both asset types to play a role, we must have that $R_s > s^\lambda R_r$. Of course this means that

$$R_s - r\left(D + C\right) > s^\lambda R_r - r\left(D + C\right) \tag{40}$$

must also follow.

Setting (40) allows us to determine the $t = 0$ choices provided that the CoCo conversion does not make a difference in the bank's actions. There are two such situations: when the bank is able to meet the liquidation incentive constraint even before conversion, and when the bank is not able to meet the liquidation incentive constraint even after conversion. We discuss them one at a time.

Consider when the bank is able to meet the LIC even without conversion. At $t = 0$, the bank compares the return from liquidating the risky asset $s^\lambda R_r - r\left(D + C\right)$, with that of the safe asset. However, (40) implies that in this case, the safe asset will always be chosen by the bank at $t = 0$, because the regulator forbears at $t = 1$, which means the bank has to pay rC to the CoCo holders. The outcome will be (Safe, Forbear, Liquidate).

Next, if the bank was not able to meet the LIC requirements even with conversion, then the regulator will forbear and the bank will gamble. However, that means that the return faced by the bank from gambling will be $s\left(R_r - r\left(D + C\right)\right)$, while that of the safe asset is $R_s - r\left(D + C\right)$. But

by the assumption in (4), the bank will always choose the risky asset at $t = 0$. The outcome will be (Risky, Forbear, Gamble).

This leaves us with the cases where conversion makes a difference in the bank's $t = 1$ decisions. We have seen in the previous section that this is only true for a limited number of situations: for a q shock, when $E_{conv} > E^* > E_{forb}$, and for a p shock, when $E_{conv} > E^* - \Delta > E_{forb}$. Whether these situations arise really depends on the initial values of D and C relative to the expected return for both the q and the p shocks. However, to be able to work back to $t = 0$ decisions, we must use the benchmark case, as the shocks are unexpected at $t = 0$. Essentially, we assume that whenever the bank falls into the $E_{conv} > E^* > E_{forb}$ case, the regulator who can bear the conversion costs will convert the CoCos.

Neither (4) nor (40) imply anything about the relative net return of the safe asset compared to the net return of having liquidated the risky asset combined with a CoCo conversion.

$$R_s - r(D + C) > s^\lambda R_r - rD. \tag{41}$$

We have to assume either this, or the alternative. This will enable us to obtain more interesting results. We must also consider the payoffs of the bank under each regulator type, assuming that the regulator type is known. However, since the regulator makes the conversion decision after the shock occurs, her decision must take the shock into account, unlike the bank's decision at $t = 0$.

6.3   High type regulator

Consider first the high-cost regulator, with costs of conversion χ_H. To ensure that the high cost regulator will always forbear regardless of shock, we assume that

$$\chi_H > \max\left[\bar{\chi}_q, \ \bar{\chi}_p\right], \tag{42}$$

where $\bar{\chi}_q$ and $\bar{\chi}_p$ were introduced in Section 2. By Lemmas 2 and 5, a high-type regulator will always forbear regardless of the type of shock, because the social benefit of conversion is lower than the cost, which is χ_H. CoCos are only useful at $t = 1$ if for a q shock, the bank faces $E_{conv} > E^* > E_{forb}$, and if for a p shock, the bank faces $E_{conv} > E^* - \Delta > E_{forb}$. But since by assumption, the regulator

faces too high costs of conversion, she will forbear, regardless. As a result, the bank will never have enough skin in the game to liquidate, therefore the bank will always gamble for resurrection at $t = 1$.

In choosing between the safe and the risky asset at $t = 0$ though, the bank gains $R_s - r(D + C)$ under the safe asset, and $s(R_r - r(D + C))$ under the risky asset while gambling for resurrection. Since at time $t = 0$, the bank is not aware of a forthcoming shock, he uses s to calculate his expected returns from the risky portfolio. However since by assumption we had that $s(R_r - r(D + C)) > R_s - r(D + C)$, the bank will always choose the risky asset whenever the regulator is of the high type, as she will always be forbearing. Therefore, the outcome here, for both the q and the p shocks, is (Risky, Forbear, Gamble).

6.4 Low type regulator

Consider next the low-cost regulator, with costs of conversion χ_L. We assume that

$$\chi_L < \bar{\chi}, \tag{43}$$

where $\bar{\chi}$ was defined in Section 4.1. Therefore, whenever $E_{forb} < E^* < E_{conv}$ under a q shock, or $E_{forb} < E^* - \Delta < E_{conv}$ under a p shock, the regulator will always choose to convert the CoCos. Therefore, at $t = 1$, the bank will use the payoff that is consistent with the regulator's choice to convert, which is $s_\lambda R_r - rD$. However, at $t = 0$, the shocks are unanticipated, so that only the benchmark case hold. In the following sections, we will consider both $R_s - r(D + C) > s^\lambda R_r - rD$ and $R_s - r(D + C) < s^\lambda R_r - rD$, and explore the resulting outcomes. However, to make the analysis meaningful, we restrict attention to only those cases where the LIC is satisfied after a conversion.

6.4.1 When the payoff of the safe asset exceeds that of the liquidated risky portfolio

Suppose that $R_s - r(D + C) > s^\lambda R_r - rD$. Then the bank will choose the safe asset at $t = 0$. If the equation holds, it must also be true that

$$rC < R_s - s^\lambda R_r. \tag{44}$$

(44) is equivalent to stating that the bank will only choose the safe asset over the risky one if the amount of CoCos is less than the gap between the gross returns of the safe asset and the liquidated risky asset. If the gap is small, then the issued CoCos must be relatively few compared to the difference in the expected returns. At $t = 0$, because the shocks are unknown, then it is enough that (44) holds in order for (Safe, Convert, Liquidate) to be a credible outcome.

Other outcomes exist but they are not consistent ones. We list them here. (Safe, Convert, Gamble) is not an equilibrium because even if the regulator decided to convert the CoCo, the bank will still choose to gamble, which is not consistent with the regulator's decision to convert. If this was the case, the regulator would deviate to Forbear, as it is costless. (Safe, Forbear, Gamble) is also not an equilibrium because this is inconsistent with the assumption on net present value. If the bank was going to gamble, then it could not pick the safe asset in the first place. Moroever, the low cost regulator will never forbear if conversion is useful. Finally, (Safe, Forbear, Liquidate) is also not an equilibrium because liquidation by the bank is not the best response to a forbearing regulator.

6.4.2 When the payoff of the liquidated risky portfolio exceeds that of the safe asset

Assume now that $R_s - r(D + C) < s^\lambda R_r - rD$. This means that the bank would choose the liquidated risky portfolio over the safe asset. It also means that

$$rC > R_s - s^\lambda R_r \tag{45}$$

must hold. This means that whenever the bank issues a large enough amount of CoCos, and provided that the bank knew that the regulator faces a low cost of conversion, the bank will choose the risky asset at $t = 0$, because the low-cost regulator will certainly convert at $t = 1$ if necessary. The condition in (45) is sufficient at $t = 0$ because the shocks are unexpected at that time. Specifically, (45) is enough to let (Risky, Convert, Liquidate) be an equilibrium outcome.

As in the previous subsection, there exist outcomes that are not consistent. We present them here, along with a brief explanation of why they do not work. (Risky, Forbear, Gamble) is not an equilibrium for the low-cost regulator, because by assumption, she will always convert the CoCos when necessary. (Risky, Convert, Gamble) is not an equilibrium, because if the bank chooses to

Gamble, then the regulator would deviate to Forbear. Finally, (Risky, Forbear, Liquidate) is not an equilibrium because liquidation is not the bank's best response to a forbearing regulator.

6.4.3 Does the size of the CoCo foreshadow expectations about shocks?

One may argue that it is inconceivable that the regulator does not foresee a shock. It is conceivable that she miscalculates the amount of the shock though. Both the regulator and the bank foresee that some negative outcomes occur, otherwise they would not assign recovery probability p to the bad loans q. Even though the bad loans are anticipated, it may be the case there would be more bad loans than expected, or perhaps that the probability of recovering those bad loans fall even more. Therefore it is interesting to see how much (partial) knowledge of a shock will affect (44) and (45).

Recently, banks have been encouraged by regulators to issue some amount of CoCos. Under Basel III, banks may have 3.5% of the 8% regulatory capital requirement based on risk-weighted assets filled by CoCos. Under the Total Loss Absorption Capacity (TLAC) Standard issued by the Financial Stability Board (FSB), globally systemic financial institutions must have loss absorption capacity that is 8% above the Basel III requirement by 2019, and may be filled by CoCos. These figures are lower bounds, and banks are free to issue more than the prescribed amounts.

While in this paper, we have modelled the shocks to be unanticipated at $t = 0$, and while we take capital structure as a given, the actual amount of CoCos issued is a bank decision, which involves the bank's expectations about the future. That is, knowing the minimum requirements for the benchmark case for certain outcomes to be equilibria, we may be able to infer something about shock expectatations by the bank and the regulator by examining the capital structure chosen by the bank, as well as the limits on CoCo issuances imposed by the regulator.

Consider a shock to q (the shock to p is similar). From (19), we know that this causes the bank's recovery value to fall from from $s^\lambda(q)$ to $s^\lambda(q')$. It also means that

$$R_s - r(D + C) > s^\lambda(q) R_r - rD > s^\lambda(q') R_r - rD, \tag{46}$$

which also implies that if the amount of CoCos are fewer than the difference between the gross

returns of the safe and the liquidated risky assets, then

$$rC < R_s - s^\lambda(q) R_r < R_s - s^\lambda(q') R_r \tag{47}$$

is true as well. In other words, even if there was knowledge about the size of the q shock, it will not be reflected in the amount of CoCos chosen at the start of the game, as long as (44) is true. However, if the amount of CoCos are greater than the difference between the gross returns of the safe and the liquidated risky assets, then

$$rC > R_s - s^\lambda(q') R_r > R_s - s^\lambda(q) R_r \tag{48}$$

is true. We can rewrite this equation as follows: letting $q' = q + \nu$, we can write $s^\lambda(q') = s^\lambda(q) - v(1-p)$, which leads to

$$rC > \left(R_s - s^\lambda R_r\right) - v(1-p). \tag{49}$$

In other words, the size of the CoCo issuance whenever (45) holds is revealing about the size of the shock that the regulator expects. This is quite interesting as CoCo issuance is highly encouraged by the regulators, as seen from the recent regulation passed by Basel III and the Financial Stability Board.

Corollary 9. *When $rC < R_s - s^\lambda(q) R_r$, the regulator's knowledge about the shock is not revealed, when $rC > R_s - s^\lambda(q) R_r$ the size of the CoCo issuance may be indicative of the regulator's belief about the size of the potential shock.*

6.5   If the regulator's type is unknown

From the previous section, we have obtained only two outcomes that are consistent with a low-cost regulator's decision to convert a CoCo in the event of a shock. Both outcomes require that the liquidation incentive constraint is satisfied: either the safe asset return exceeds the return from the liquidated risky portfolio ($rC < R_s - s^\lambda R_r$), or the returns from the liquidated risky portfolio exceeds the safe asset return ($rC > R_s - s^\lambda R_r$).

However, it is not always the case that the bank knows exactly the type of regulator that he is dealing with. If the regulator's type is unknown, the bank must make its $t = 0$ decisions based on

its beliefs about the type of regulator. In this section, we characterize the beliefs of the bank. Note that given the regulator's type, the regulator's action is always known. Let β represent the bank's belief that the regulator is of the low-cost type, and $1 - \beta$ be the bank's belief that the regulator is of the high-cost type. We already know that the high-type will always forbear, and the bank gains $R_s - r(D + C)$ under the safe asset, and $s(R_r - r(D + C))$ under the risky asset (while gambling for resurrection), because they calculate at $t = 0$, where the shock is not expected to happen.

6.5.1 Suppose there were relatively few CoCos $\left(rC < R_s - s^\lambda R_r\right)$

We have seen that the only time that a safe asset will be chosen under the low-cost regulator is when $rC < R_s - s^\lambda R_r$. The payoff of the bank under $t = 1$ choice (Convert, Liquidate) is $s^\lambda R_r - rD$, and the payoff of the bank under $t = 1$ choice (Forbear, Gamble) is $s(R_r - r(D + C))$. The shocks do not appear because ex ante the bank puts zero probability on the occurence of a crisis. Therefore, the bank will only choose the safe asset if (50) holds:

$$R_s - r(D + C) > \beta \left[s^\lambda R_r - rD \right] + (1 - \beta)\left[s(R_r - r(D + C)) \right]. \tag{50}$$

β and $1 - \beta$ do not appear in the safe side because the safe asset pays exactly the same under any type of regulator.

By the assumption in (4), we have that $s(R_r - r(D + C)) > R_s - r(D + C)$. If we assume that $rC < R_s - s^\lambda R_r$, it must be that $s^\lambda R_r - rD < R_s - r(D + C)$. This means that $s^\lambda R_r - rD < R_s - r(D + C) < s(R_r - r(D + C))$. Therefore there must exist a $\beta \in [0, 1]$ that makes (50) hold exactly, as because we only need a linear combination of a high and a low outcome. Call this $\bar{\beta}$. If the bank's belief is $\beta = \bar{\beta}$, the bank randomly chooses between the safe and the risky asset. On the other hand, if the bank's beliefs about the low-cost regulator is such that $\beta < \bar{\beta}$, the bank will choose the risky asset, otherwise, the bank chooses the safe asset. We have the following proposition:

Proposition 10. *With imperfect information about the regulator type, and when $rC < R_s - s^\lambda R_r$, there exists a threshold belief $\bar{\beta} \in [0, 1]$ that leads a bank to be indifferent between a safe an a risky asset at $t = 0$. If $\beta \leq \bar{\beta}$, the bank chooses the risky asset at $t = 0$ and eventually decides to liquidate, if $\beta > \bar{\beta}$, the bank will choose the safe asset at $t = 0$.*

6.5.2 Suppose there were relatively many CoCos $\left(rC > R_s - s^\lambda R_r\right)$

The only other case consistent with a low-cost regulator choosing to convert the CoCos is when $rC > \left(R_s - s^\lambda R_r\right)$ This means that even if the LIC holds in a crisis, the bank's payoff under the liquidation of the risky asset is still higher than the payoff of the safe asset. Therefore, even if the regulator type is known to be low, the bank will choose the risky asset because the liquidation value after conversion is higher than the yield of the safe asset.

By the assumption in (4), we have that $s\left(R_r - r\left(D + C\right)\right) > R_s - r\left(D + C\right)$. Also, the assumption $rC > \left(R_s - s^\lambda R_r\right)$ is equivalent to $s^\lambda R_r - rD > R_s - r\left(D + C\right)$. However, the left hand side of (50) is $R_s - r\left(D + C\right)$, while the right hand side is a linear combination of $s^\lambda R_r - rD$ and $s\left(R_r - r\left(D + C\right)\right)$, which are both larger than $R_s - r\left(D + C\right)$. Therefore, no value of $\beta \in [0,\ 1]$ will make (50) true. In short, we would have for any β then, it would always be true that

$$R_s - r\left(D + C\right) < \beta\left[s^\lambda R_r - rD\right] + \left(1 - \beta\right)\left[s\left(R_r - r\left(D + C\right)\right)\right], \tag{51}$$

meaning the safe asset will never be chosen at $t = 0$. This leads to the following proposition:

Proposition 11. *With imperfect information about the regulator type, and when $rC > \left(R_s - s^\lambda R_r\right)$ holds, there is no belief that is consistent with the bank choosing a safe asset at $t = 0$.*

From the preceding sections, it is clear that conversion is useful for letting the liquidation incentive constraint be satisfied after a crisis, but does not guarantee that a safe choice is induced ex ante. This is because the choice depends on on the relative gains of the occurence of a conversion: whether $rC < R_s - s^\lambda R_r$. That is, in order for CoCos to be effective deterrents ex ante, there must not be too many of them to begin with. *However, for CoCos to be useful at $t = 1$ in terms of loss absorption capacity, there must be sufficiently many of them.* It is alarming that safe choices are induced only when rC is small. Therefore CoCo issuance may actually be inviting risk shifting at $t = 0$. While CoCos undoubtedly increase loss absorption capacity ex post, they may encourage risk-shifting ex ante.

7 Conclusion

CoCos are perceived to be promising for increasing the loss-absorption capacity of banks. However, the manner of their conversion leaves room to be desired - in addition to the conversion based on the book value of the bank's equity, there is also conversion based on regulatory discretion. While the literature has considered regulatory forbearance, it has not done so in the context of CoCos. Others in the literature have espoused that CoCos are very good as commitment devices. However, precisely because the conversion is not really automatic, in the sense that book values have a delay, and that regulators do have discretion and also bear some costs of conversion, we argue that CoCos will only be converted in a limited set of circumstances.

We have modeled a sequential three period game between the regulator and the bank. The bank can choose between safe and risky assets at the start, and are potentially subject to a shock at the next period. Based on the severity of the shock, the regulator can decide to convert the CoCos, or forbear on the conversion. The bank can then choose between liquidating the risky assets, and gambling for resurrection. However, the bank's choice rests on whether its liquidation incentive constraint is met. It turns out that the type of shock matters: the constraint is loosened upon a shock on the probability of obtaining returns from the bad loans, but does not changes when instead it is a shock on the proportion of loans that turned out to be bad. It turns out that the regulator will only convert the CoCos if it makes a difference in the bank's choice between liquidation and gambling. In particular, this will only happen if the conversion is enough to make the bank's skin in the game sufficiently high to do the right thing.

The regulator will only convert the CoCos if in addition to being able to change the bank's decision, the regulator is able to face the costs of conversion. We have cast the cost of conversion in terms of an increase in the threshold belief of the depositors that are necessary to prevent the occurence of bank runs. Risk neutral depositors are assumed to have beliefs regarding the bank's initial choice, as well as on the likelihood of obtaining positive returns on the risky asset, that satisfy an incentive compatibility constraint. However, as conversion will never happen with a safe asset, observing a conversion can only mean that the bank had chosen a risky one instead. This leads the run probability to go up, providing a reason for the regulator to forbear on conversion.

If banks knew the conversion costs that the regulator is facing, the outcomes would be clear. A

regulator who faces high conversion costs will never convert a CoCo, leading to the bank choosing a risky asset at the start, and to gamble for resurrection in the event of a shock, in the event that the liquidation incentive constraint is not met. A regulator who faces low conversion costs will always convert a CoCo, but as to whether or not this is sufficient to induce a safe choice at the start depends on whether the liquidation value of the asset ex ante exceeds that of the safe asset. This decision can be recast in terms of how much CoCos are issued at the beginning. One can think of the conversion as delivering a relative gain to the bank equal to the amount of the converted CoCo, and delivering a relative opportunity cost equal to the difference between the returns of the safe asset and the liquidated risky asset.

We find that only when the CoCos are sufficiently few will there be any incentive for the bank to choose the safe asset in the first place. When there are too many CoCos, in a sense we make precise in this paper, the bank anticipates regulatory forbearance, and therefore will find it more attractive to choose the risky asset at the start. This makes CoCos not very convincing in reducing ex ante risk. There is a clear tradeoff between mitigating risk ex ante and improving loss absorption capacity ex post. Only when the bank's safety net is reduced, in the sense that there will be no significant changes in the equity ratio of the bank post conversion, will the regulator be able to hope that CoCo conversion will act as a deterrent in choosing risky assets to begin with.

The beliefs about the regulator's type must be managed well. This is because learning about the regulator's type will influence future decisions of the bank. While we do not model it here, it is a direction for future research. A regulator who cultivates a reputation for forbearance will encourage risky investments, while a regulator who cultivates a reputation for being tough will encourage safe investments only if the banks gain sufficient skin in the game after a conversion. It becomes important to manage the regulator's reputation in order to influence the beliefs of the bank as well.

Seen from a post-crisis perspective, the conversion of CoCos aligns the incentive of the bank with the incentive of the regulator. However, this treats the asset choices as a given. Moving forward, the banks are at liberty to rebalance their portfolio as they see fit, taking into account the type of regulator that they are dealing with. Therefore, there must be some merit in keeping the regulator type opaque in order to induce safer choices. However, given that there are limited circumstances in which the conversion will be useful, it seems that the CoCos were created with the forbearing regulator in mind.

Appendix

A The impact of dilutive CE CoCos on a bank's $t = 1$ and $t = 0$ decision

The bank's $t = 1$ decision on whether to gamble for resurrection or liquidate bad assets depends on its skin in the game, which means that it depends on the bank's outstanding liabilities at that time. When the CoCo is of the principal writedown type, the conversion of the CoCo immediately eliminates a part of the bank's liability, without altering who owns the residual equity. This feature of the principal writedown CoCo allows us to use the liquidation incentive constraint described in (11) to determine whether CoCo conversion would be useful in changing a bank's decision. This is because the liquidation incentive constraint is cast purely in terms of the threshold liabilty required in order to induce a certain decision.

When the CoCo is of the convert-to-equity variety, it is more complicated, because it alters the share held by the original equity holder. Such CoCos are dilutive in the sense that each unit of CoCo is transformed to some share of equity. However, since the regulator's decision to convert precedes the bank's second decision point, the degree of dilution does not matter. As such, the original equity holders make their decision based on the liquidation incentive constraint (11). On the other hand, dilution might matter for $t = 0$ decisions.

Let the conversion rate faced by the CoCo holders be ψ, which we call the dilution parameter. Conversion transforms the CoCos from rC liabilities into ψrC equity. This means that the equity holders get rid of the CoCo liability, but must share with the CoCo holders-turned-equityholders. We normalize the equity held by the original shareholders to 1. Since the regulator only converts the CoCo to induce the bank to choose liquidation, the bank will only liquidate when

$$\frac{s^\lambda R_r - rD}{1 + \psi rC} \geq \frac{s(R_r - rD - rC)}{1 + \psi rC}. \tag{52}$$

Therefore, in assessing which asset to choose at $t = 0$, the values that will be carried over will be the diluted ones. Suppose that liquidation is more attractive than gambling for resurrection. Then

the bank would only choose the safe asset if

$$R_s - r(D + C) > \frac{s^\lambda R_r - rD}{1 + \psi rC}. \tag{53}$$

In Section 6.3, we have considered two possibilities about $s^\lambda R_r - rD$ and $R_s - r(D + C)$. If there were relatively few CoCos, it would be that $R_s - r(D + C) > s^\lambda R_r - rD$ in which case, any nonnegative value of ψ can induce a safe choice ex ante, as can be seen from (52).

However, if there were relatively many CoCos, it follows that $R_s - r(D + C) < s^\lambda R_r - rD$. We can find a value of ψ that is enough to cause the inequality in (53) to just bind, as in (54):

$$\psi \geq \frac{1}{rC} \left[\frac{s^\lambda R_r - rD}{R_s - r(D + C)} - 1 \right] = \bar{\psi}. \tag{54}$$

It is easier to convince a bank to choose the safe asset at $t = 0$ if it has to share the gains with the new shareholders if the regulator had to convert. One can also find a threshold that makes the safe asset more attractive than gambling for resurrection, by finding ψ that solves

$$R_s - r(D + C) > \frac{s(R_r - rD - rC)}{1 + \psi rC}.$$

Note that a high dilution parameter is not a solution for regulatory forbearance. It only works if the bank believes that the regulator is willing to convert the CoCo,which she will do only if her costs of conversion is low enough.

B   Calculations for various results in the chapter

B.1 Calculation for (32)

In the event of a p shock, the bank's debt threshold is

$$B \leq \left(\frac{\lambda - p'}{1 - p'} \right) R_r = B_p^*.$$

Writing $p' = p - \delta$, we may write B_p^* as follows.

$$
\begin{aligned}
B_p^* &= \left(\frac{\lambda - (p - \delta)}{1 - (p - \delta)}\right) R_r \\
&= \left[\left(\frac{\lambda - p}{1 - (p - \delta)}\right) + \left(\frac{\delta}{1 - (p - \delta)}\right)\right] R_r \\
&= \left[\left(\frac{\lambda - p}{1 - p}\right)\left(\frac{1 - p}{1 - p + \delta}\right) + \left(\frac{\delta}{1 - (p - \delta)}\right)\right] R_r
\end{aligned}
$$

Recall B^* as defined in (12). Since B^* is decreasing in p, $B_p^* > B^*$. Let $\Delta = B_p^* - B^*$. We can then write

$$
\begin{aligned}
\Delta &= \left[\left(\frac{\lambda - p}{1 - p}\right)\left(\frac{1 - p}{1 - p + \delta}\right) + \left(\frac{\delta}{1 - (p - \delta)}\right)\right] R_r - \frac{\lambda - p}{1 - p} R_r \\
&= \frac{\lambda - p}{1 - p} R_r \left[\left(\frac{1 - p}{1 - p + \delta}\right) - 1\right] + \left(\frac{\delta}{1 - p + \delta}\right) R_r \\
&= \frac{\lambda - p}{1 - p} R_r \left(\frac{1 - p - 1 + p - \delta}{1 - p + \delta}\right) + \left(\frac{\delta}{1 - p + \delta}\right) R_r \\
&= \frac{\lambda - p}{1 - p} R_r \left(\frac{-\delta}{1 - p + \delta}\right) + \left(\frac{\delta}{1 - p + \delta}\right) R_r \\
&= \frac{\delta R_r}{1 - p + \delta}\left(\frac{1 - \lambda}{1 - p}\right),
\end{aligned}
$$

leading to the expression in (32).

B.2 Calculation for (38)

The difference between the payoffs of forbearance and conversion for the safe asset may be written as

$$
\begin{aligned}
&\underbrace{\left[(1 - \bar{\alpha}) R_s + \bar{\alpha}(R_s - 1)\right]}_{forbearance} - \underbrace{\left[(1 - \bar{\alpha}') R_s + \alpha'(R_s - 1)\right]}_{conversion} \\
&= R_s \left[1 - \bar{\alpha} - 1 + \bar{\alpha}'\right] + (R_s - 1)(\bar{\alpha} - \bar{\alpha}') \\
&= R_s (\bar{\alpha}' - \bar{\alpha}) - (R_s - 1)(\bar{\alpha}' - \bar{\alpha}) \\
&= (\bar{\alpha}' - \bar{\alpha})[R_s - R_s + 1] \\
&= \bar{\alpha}' - \bar{\alpha}.
\end{aligned}
$$

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