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Equity, debt and moral hazard: the optimal structure of banks' loss absorbing capacity

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Abstract

This paper develops a model to analyse the optimal *ex-ante* capital and total loss absorbing capacity (TLAC) requirements, and the *ex-post* resolution policy of banks. Banks in our model are subject to two types of moral hazard: i) *ex-ante*, they have the incentive to shirk on project monitoring, thus increasing the risk of failure, and ii) *ex-post*, poorly capitalised banks have the incentive to engage in asset substitution by 'gambling for resurrection'. *Ex-ante* moral hazard can be eliminated by ensuring that banks have sufficient capital and uninsured 'bail-inable' debt, while *ex-post* moral hazard is mitigated by triggering resolution when the minimum capital requirement is breached. We argue that optimal regulation consists of a high TLAC requirement and high capital buffer. Our analysis also suggests that higher system-wide risk would call for a higher capital buffer, but TLAC could be lowered if it does not jeopardise the credibility of bail-in itself.

Key words: Bank capital, bank capital regulation, total loss absorbing capacity, bank resolution.

JEL classification: G21, G28, G33, G38.

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1 Introduction

A key aim of the post-crisis global regulatory reform effort has been to end the problem of large globally, systemically important banks (G-SIBs) being 'too big to fail' (TBTF). A bank is 'too big to fail' if it is so large that its failure could destabilise the entire financial system so that public authorities are compelled to bail it out by providing financial assistance to prevent a systemic failure. The expectation of such a bailout in turn encourages its shareholders and executives to take socially excessive risks, thus increasing the expected liabilities for taxpayers.

The post-crisis regulatory reforms included a number of new requirements for G-SIBs, aimed at ending 'too big to fail'. First, G-SIBs are required to maintain a higher capital ratio during normal times relative to the smaller, less systemic banks. Under the new Basel III capital regulation, banks are subject to minimum capital *requirements* and *buffers*: whereas the minimum capital requirements must be met at all times, banks can deplete capital *buffers* to absorb unexpected losses on their asset portfolios without entering resolution. In addition to these requirements under the Basel III, G-SIBs are also required to maintain an additional capital buffer in normal times, reflecting their greater impact on systemic stability. Second, the Financial Stability Board also introduced a new total loss absorbing capacity (TLAC) requirement applicable to G-SIBs from 1 January 2019. TLAC may consist of capital instruments which count towards the minimum capital requirements, and other eligible unsecured debt instruments with residual maturity of over one year. The primary aim of the TLAC requirement is to ensure that there is sufficient loss-absorbing and recapitalisation capacity available in resolution to implement an orderly resolution of bank failures, reducing potential systemic instability and recourse to taxpayer funds.[1] The Financial Stability Board (FSB) (2015) suggests that "a breach or likely breach of Minimum TLAC should be treated as severely as a breach or a likely breach of minimum capital requirements".

In this paper, we develop a simple framework in order to examine the optimal setting of the triplet of regulatory requirements: a minimum capital requirement and a minimum TLAC requirement, both of which need to be met at all times, and a capital *buffer* requirement, which banks are required to maintain in normal times but can deplete to absorb losses in stressed conditions without entering resolution. In our model, banks are

[1] Financial Stability Board (2015).

funded by equity, long-term unsecured (bail-inable) debt, and insured deposits. Equity is privately and socially costly relative to the unsecured debt and insured deposits, reflecting a higher transaction cost of equity issuance. However, equity has the advantage of absorbing losses without creating wider social costs whilst the bank remains a going concern i.e. whilst the amount of equity is non-negative. In contrast, a "bail-in" of unsecured debt holders in which some or all of the interest and principal is written down will require a modification of the contract which it has been argued could potentially generate social deadweight costs, including legal and administrative costs incurred by the bank and resolution authority, and could in certain circumstances lead to contagion by triggering a generalised freeze of unsecured debt market for other systemic banks.[2] Finally, 'bail-out' of either insured depositors or other creditors is funded by distortionary taxation which creates a deadweight cost.

Our model also incorporates two moral hazard problems, which are dependent on the bank's funding structure: i) *ex ante*, banks that maximise shareholder returns have the incentive to shirk on costly project monitoring efforts in the presence of flat-rate deposit insurance, thus increasing the risk of a failure, and ii) *ex post*, poorly capitalised, limitedly liable banks have the incentive to engage in asset substitution by taking excessive risks at the expense of the deposit insurance fund (or taxpayers) and the long-term unsecured debt holders. Thus, the regulator optimally sets the trio of regulatory requirements to eliminate these two types of moral hazard, while trading-off the *ex ante* and *ex post* costs and benefits of equity against debt and deposits as outlined above.

Our analysis yields the following key results. First, we demonstrate that the *ex-ante* moral hazard problem can be addressed by ensuring that, in the event of a bank failure, private investors (as opposed to taxpayers) will absorb sufficient amount of losses. That means that the regulator needs to ensure that the TLAC *plus* equity capital buffer is sufficiently high *ex ante*, but the *composition* of this private loss absorbing capacity is irrelevant for *ex ante* moral hazard when bail-in is fully credible and unsecured debt market can price risks and penalise risk-taking through a higher interest rate. Second, we show that the resolution authority needs to intervene and 'bail in' unsecured debt as soon as the minimum capital requirement is breached. Hence, the minimum capital requirement should be set at a level such that the shareholders of those banks that meet

[2]As suggested by Goodhart and Avgouleas (2014).

the requirement have sufficient 'skin in the game' to not engage in socially suboptimal asset substitution. Third, the optimal level of capital buffer is determined by a trade-off between the social cost of equity issuance and the benefit of reducing the probability and the cost of a bank failure.

Our simple framework also enables an analysis of how changes in economic conditions might alter the optimal trio of regulatory requirements. Our analysis suggests that a higher bail-in cost calls for a higher capital buffer and a lower TLAC requirement, whereas a higher bail-out cost calls for both the capital buffer and the TLAC requirement to be raised. Furthermore, our analysis suggests that, in response to an elevated risk of a system-wide shock, the regulator may want to increase the capital buffer while *reducing* the TLAC requirement. This is because an increased risk of a system-wide shock increases the expected cost of bank insolvency, and a higher capital buffer relative to TLAC-eligible debt helps to reduce the risk of bank insolvency.

Our paper is related to a number of existing papers that have examined the impact of capital requirements on banks' risk-taking incentives. The traditional view is that increased capital requirements promote social welfare by curtailing banks' incentives to shift risks onto the taxpayers when banks are limitedly liable and benefit from implicit (e.g. the expectation that creditors will be bailed out as the bank is TBTF) or explicit (e.g. flat-rate deposit insurance that is not actuarially fairly priced) government guarantees (e.g. Keeley, 1990; Rochet, 1992). This view has been challenged by more recent studies which suggest a more nuanced effect. For example, Hellman et al (2000) show that capital requirements have two counteracting effects on the incentive for a bank to take on a more risky investment project. On the one hand, an increase in capital requirements increases shareholders' 'skin in the game' by putting more of the their equity capital at risk: this has the effect of reducing the incentive to take on risk. But on the other hand, an increase in capital requirements also reduces the bank's profit margin, thus eroding its franchise value and incentivising it to take on greater risks. The authors conclude that the overall effect of capital requirements on banks' risk-taking is ambiguous. Allen *et al.* (2011) show how optimal capital regulation depends on the presence of deposit insurance, and competition in the deposit and credit markets. With perfect competition for uninsured deposits, there would be no need for capital regulation as market discipline induces banks to maintain some capital to ensure that they have skin in the game, resulting in a lower deposit interest rates. If deposits are insured, however, a moral hazard problem arises as limitedly liable banks may shift risk onto the deposit insurance (given flat-rate deposit insurance).[3] In our model, the presence of limitedly liable banks which are partly financed by insured deposits yields the same incentive to shift risk onto the deposit insurance fund.

In addition to the impact on banks' *ex-ante* incentives to take risk, bank capital also has a role in acting as a buffer between the asset portfolio realisation and liabilities, reducing the probability and cost of failure (Dewatripont and Tirole, 1994). Our model captures both the skin-in-the-game and buffer views of capital regulation, as the bank's liability structure determines its incentives to invest in riskier projects, as well as the probability of a risk-shifting problem arising ex-post.

Furthermore, our paper considers the optimal minimum capital requirement, TLAC requirement, and capital buffer in a single framework, reflecting the new regulatory environment for G-SIBs. Given the new nature of these requirements, there has been little research in this area to date, although a number of existing papers have examined the issue of how contingent-convertible bonds (Cocos) and bail-inable debt might affect banks' incentives. For example, Martynova and Perotti (2015) analyse how contingent-convertible bonds affect banks' risk-taking behaviour, and argue that Cocos that trigger when banks are solvent will reduce their risk-shifting incentives more than bail-in bonds, which they assume will convert into equity or be written down only when the bank becomes insolvent. While we do not explicitly examine the role of Cocos, we also argue that, for bail-in bonds to reduce banks' (ex post) risk-shifting incentives, they need to convert while equity value is still positive. We also examine how a bank's ex ante risk-taking incentives are influenced by the funding mix and show that equity and bail-in debt have the same disciplining effect on banks.

Finally, our paper is also related to the literature on bank failure resolution. In our model, the rationale for resolution arises due to the need to intervene promptly to prevent undercapitalised banks from 'gambling for resurrection' by investing in excessively risky but high return assets, as in Tanaka and Hoggarth (2006) and De Niccolo et al (2014). The existing literature has also examined the possibility of time-inconsistent resolution authority (e.g. Mailath and Mester, 1994). In our analysis, the resolution authority can credibly intervene as soon as the bank breaches the minimum capital requirement whilst

[3]The key aspect of this assumption is that the deposit insurance is not actuarily fairly priced so the interest rate demanded by depositors is not dependent on the riskiness of the banks asset portfolio.

the bank is still solvent because allowing undercapitalised banks to continue operating will encourage them to gamble for resurrection and magnify the losses for unsecured debt holders and the deposit insurance fund and expected social cost of resolution. Thus, resolution is time-consistent in our model.

The rest of the paper is organised as follows. Section 2 develops the baseline model, in which the probability of a bad state, or a system-wide shock – which reduces asset return for all banks – is assumed to be exogenous: thus, we focus on the impact of *ex-post* moral hazard in the baseline analysis. Section 3 solves for the model equilibrium and clarifies the determinants of the optimal regulatory requirements. Section 4 endogenises the probability of the bad state, which is now determined by banks' decisions about whether to monitor the project or not. This extended model allows us to analyse policies to mitigate *ex-ante* moral hazard. Section 5 concludes.

2 The model

This section outlines our baseline, three-period model. We assume that the regulator initially imposes regulatory requirements consisting of a minimum capital requirement, a TLAC requirement, and a capital buffer on ex-ante identical banks. There are two macroeconomic states of the world, H ('good') and L ('bad'), which determine the interim return that banks receive. Banks are *ex-post* heterogeneous, because in the bad state, they receive different returns, which are unknown *ex ante*. In the baseline model, banks are only subject to ex-post moral hazard: banks with little skin in the game (i.e. returns net of liabilities) have the incentives to engage in asset substitution – or gamble for resurrection – in order to maximise shareholder returns at the expense of the unsecured debt holders and the deposit insurance fund (DIF). The presence of this ex-post moral hazard creates a case for the resolution authority to intervene and resolve undercapitalised banks in order to prevent them from failing with larger losses – which also imply larger social costs – at a later date.

2.1 Ex-ante regulatory requirements and investment (t=0)

There are three periods: $t = 0, 1, 2$. All agents are risk-neutral, and the banking sector consists of a continuum of *ex ante* identical banks of mass 1. At *the start* $t = 0$, *ex ante* identical banks each have an investment opportunity which requires a unit of funds, and the regulator sets rules on how it should be funded. The bank can fund its investment using three different types of instruments to maintain the following balance sheet identity:

$$E_0 + G + D = 1$$

where E_0 is initial ($t = 0$) equity investment; G is uninsured, unsecured debt; and D is the insured deposits. We define the 'private loss absorbing capacity' as $\theta \equiv E_0 + G$, and the share of equity within this as e_0. Hence, the items on the liability side of the balance sheet can be rewritten as: $E_0 = \theta e_0$, $G = \theta(1 - e_0)$, and $D = 1 - \theta$. Debt and deposits mature at $t = 2$, and their holders are repaid the full principal and interest if the bank is solvent, whereas equity holders receive the residual value. The maturity assumption about the uninsured debt G is appropriate, because unsecured debt with residual maturity of one year of less cannot be used towards meeting the TLAC requirement. The maturity assumption about the insured deposit D is without loss of generality, because insured depositors have no incentive to run on their banks or demand a higher risk premium in rolling over the deposits at $t = 1$. We assume that, if a bank is insolvent, then equity holders are wiped out, whereas the uninsured debt holders receive the residual return.

As explained in Section 2.2, the regulator can also 'resolve' the bank if it is found to be in breach of the minimum capital requirement at $t = 1$. Some banks that are resolved at $t = 1$ are balance sheet solvent, even though they are in breach of the minimum capital requirement: in this case, none of the claimholders will suffer any losses. If, however, a bank is found to be insolvent at $t = 1$, equity holders receive zero, whereas the uninsured debt holders receive the residual return after depositors are repaid. The interest rate i on the unsecured debt G factors in the state of the world in which the unsecured creditors are bailed in so that $i \geq 1$ (where the safe rate of return is normalised to equal 1), with strict equality depending on the return R_L in the bad state of the world as shown below. By contrast, insured deposits have a unit gross return in all states of the world, because the deposit insurance fund (DIF) will cover any shortfall if the bank has insufficient resources to pay depositors. The DIF is funded by flat-rate contributions which for simplicity we normalise to zero.[4]

[4]Insured deposits can be also interpreted as any debt liabilities that are expected to be bailed out by the government in the event of a bank failure.

We assume that, when setting regulatory requirements, the regulator knows that the bank can invest in a project that yields a ‘high’ return equal to R_H in the ’good’ macroeconomic state, which occurs with probability q, and a ‘low’ return $\tilde{R}_L$ in the ’bad’ state which occurs with probability $1-q$ at $t=1$: $1-q$ could be interpreted as the probability of a system-wide stress which reduces return on assets across the banking sector. In this section we assume that q is exogenous, but in Section 4 we endogenise the choice of q.

We assume that, in the ‘good’ macro state when $R = R_H$, banks will be solvent with certainty: $R_H > (1-\theta) + i\theta(1-e_0)$, where i is the interest rate on unsecured debt. *At the start of* $t = 0$, however, the low return is stochastic, with $\tilde{R}_L \sim Unif[0, R^{max}]$, where $R^{\max} \leq R_H$, and we assume that banks and the regulator only know the distribution of the low return. Thus, the solvency of each bank in the ‘bad’ macro state depends on the realisation of R_L relative to its liabilities $D + G$. We interpret R_L as bank ‘type’ which is *ex ante* uncertain, and the regulator sets all requirements without observing the realised R_L for individual banks.

The regulator sets the following requirements, which are expressed as a ratio of the bank’s (unweighted) assets:

1. the minimum capital requirement E^* which the bank has to maintain both at $t = 0$ and $t = 1$ in order to remain in business until $t = 2$;

2. the capital buffer, denoted E^b, which the bank can use to absorb losses at $t = 1$ without facing resolution when the return on assets turns out to be low;

3. the minimum TLAC requirement τ^*.

Note that, throughout our analysis, the risk weights are normalised to one, such that capital ratios are defined as equity (which is equal to the value of assets minus the value of liabilities) divided by the value of assets; and as the value of assets is equal to one at $t = 0$, E_0 can be interpreted as both the level of capital and the capital ratio. At $t = 0$, the TLAC requirement can be satisfied using regulatory capital instruments that are not used to meet regulatory capital buffers, $E_0 - E^b$, and uninsured debt, G. As the capital buffer can be depleted to absorb losses at $t = 1$, the TLAC requirement is satisfied as long as the sum of equity at $t = 1$, denoted as E_1, and the uninsured debt G exceeds the minimum TLAC ratio τ^* multiplied by the value of the bank’s assets at $t = 1$. Formally, the minimum capital and TLAC requirements and capital buffers are given by (1), (2) and (3), respectively, where B_t is the bank's balance sheet size at time t, which is equal to 1 at time $t = 0$ and either R_H or R_L at time $t = 1$, and (3) exploits the fact that $B_0 = 1$.

$$E_t \geq E^* B_t \forall t \in \{0,1\} \tag{1}$$

$$E_t + G \geq \tau^* B_t \forall t \in \{0,1\} \tag{2}$$

$$E_0 - E^* \geq E^b \text{ at } t = 0 \tag{3}$$

At $t = 0$ the bank has to satisfy all of the above requirements in order to start operating, whereas at $t = 1$ the bank needs to satisfy both (1) and (2) in order to avoid resolution. As we detail in the subsequent sections, the regulator chooses these requirements in order to maximise the social welfare, taking into account the following considerations:

1. The minimum capital ratio requirement E^* needs to be set at a level below which it can intervene to prevent undercapitalised banks from engaging in asset substitution ('gambling for resurrection').

2. The capital buffer E^b needs to be set at levels that enable banks to absorb some losses without facing resolution, while taking into account the social cost of equity funding relative to debt and deposits.

3. The TLAC requirement τ^* needs to be set at levels that represents the best trade-off between the cost of bail in (of uninsured creditors) and the cost of bail out (of depositors).

At the end of period $t = 0$, R_L is realised for each bank and becomes publicly observable: this makes banks heterogeneous *ex post*. Each bank then chooses the amount of deposits, uninsured debt and equity to issue, subject to regulatory constraints (1), (2), and (3). We assume that all of the depositors, unsecured creditors and equity holders are risk neutral and have access to a safe asset which yields a certain return normalised to equal 1.

The assumptions of a risk-insensitive deposit insurance premium creates a departure from the Modigliani and Miller's (1958) result that, in a frictionless world, a firm's total cost of funding is independent of its funding structure. In our model, insured deposits are the least costly form of funding for banks, as they benefit from the implicit subsidy provided by the deposit insurance fund. The unsecured debt is the second most expensive form of funding, as the unsecured debt holders demand a premium over the safe interest rate (normalised to 1) in order to be compensated for the credit risk (see Section 3.3 below). In addition, following the existing corporate finance literature, we assume that equity capital is most costly, and a bank incurs a *private* cost $\delta \equiv 1 + \delta_s$ in issuing equity, where 1 reflects the equity investors' opportunity cost of funding (given by the safe rate of return) and δ_s captures the (deadweight) transaction cost associated with equity issuance. The transaction cost could, for example, reflect the agency cost of overcoming the asymmetric information problem between the bank's potential equity investors and its executives, e.g. through cumbersome disclosure. As Myers and Majluf (1984) have shown, the cost of equity issuance is higher than the cost of debt issuance as the executives who have inside information about the bank's assets and investment opportunities have an adverse incentive to issue equity when equity is overvalued. Thus, in our model, δ_s captures the *social* cost of requiring banks to issue more capital, as we discuss more in detail in Section 3.4. As the issue of whether requiring banks to fund themselves with more capital is *socially* costly or not has been a controversial one, we will also consider explicitly in Section 3.4 the regulatory implications of having no social cost of equity issuance.

Thus, as we demonstrate formally in Section 3.3, banks' capital and TLAC regulations are binding in equilibrium: banks only issue as much equity and unsecured debt as required by the regulator, in order to maximise the benefit derived from the implicit subsidy provided by the deposit guarantee.

We have chosen to model the sequence of events at $t = 0$ as above for two main reasons. First, we want to allow for the possibility of bank failures, by capturing the fact that the regulator typically sets requirements without full knowledge of how each bank would perform under stressed conditions. If the regulator can set all requirements separately for individual banks based on perfect knowledge of the performance of their assets under all states of the world (i.e. R_L for each bank is known at the start of $t = 0$), then bank failures can be entirely eliminated by setting the capital requirements sufficiently high to ensure that $R_L > D + G$, and hence we will not have an interesting problem to analyze. Second, we also wanted to ensure that unsecured debt fully prices in the credit risk, in order to examine the role it plays in providing market discipline and mitigating *ex ante* moral hazard, which we will analyze in Section 4.

2.2 Resolution and bail-in in the interim period (t=1)

At time $t = 1$, the macroeconomic state is realised. Each bank receives the interim return, which is either R_H or R_L depending on the macro state, and this will determine its capital ratio at $t = 1$:

$$E_1 = R - D - iG \text{ where } R \in \{R_L, R_H\} \tag{4}$$

If the interim return is R_L and R_L is sufficiently low, such that a bank does not meet the pre-specified minimum regulatory capital *ratio* E^*, the regulator (or the resolution authority) triggers 'resolution', and converts unsecured debt into equity in order to recapitalise the bank, or writes down the value of the debt ('bail in').[5] Specifically, we assume that the regulator triggers resolution if the following condition holds:

$$E_1 = R_L - (1 - \theta) - i\theta(1 - e_0) < E^* R_L \tag{5}$$

The consequence of resolution and 'bail in' is explained more fully in Section 3. We assume that, in the absence of resolution at $t = 1$, a bank can choose between reinvesting the interim return either in a risky or a safe asset. The risky asset yields a gross return $\gamma > 1$ at $t = 2$ with probability p and 0 with probability $1 - p$, whereas the safe asset is a simple storage technology which yields a unit gross return at $t = 2$. We assume that the risky asset has a negative net present value, such that $p\gamma < 1$ (at $t = 1$). Thus, the socially optimal choice is for the bank to reinvest its asset return at $t = 1$ in the safe asset. However, the presence of long-term debt, which only needs to be repaid at $t = 2$, and flat-rate (and therefore non-actuarially-fairly-priced) deposit insurance both create the incentive for the bank's shareholders to 'risk shift', i.e. to take excessive risks at the expense of debt holders so as to maximise shareholder returns. As we demonstrate in Section 3, undercapitalised banks have the incentive to 'gamble for resurrection' by

[5] We assume that the resolution authority can resolve the bank without reducing the asset value of the bank, R_L. Thus, unsecured debt holders will suffer losses only when the bank is balance sheet insolvent, i.e. $R_L < D + iG$.

investing in risky assets at $t = 1$, thus magnifying the expected losses for creditors and the DIF.[6] Thus, the minimum capital requirement E^* needs to be set in such a way to allow the regulator to intervene to prevent this privately optimal but socially sub-optimal gambling behaviour, once this threshold is breached.

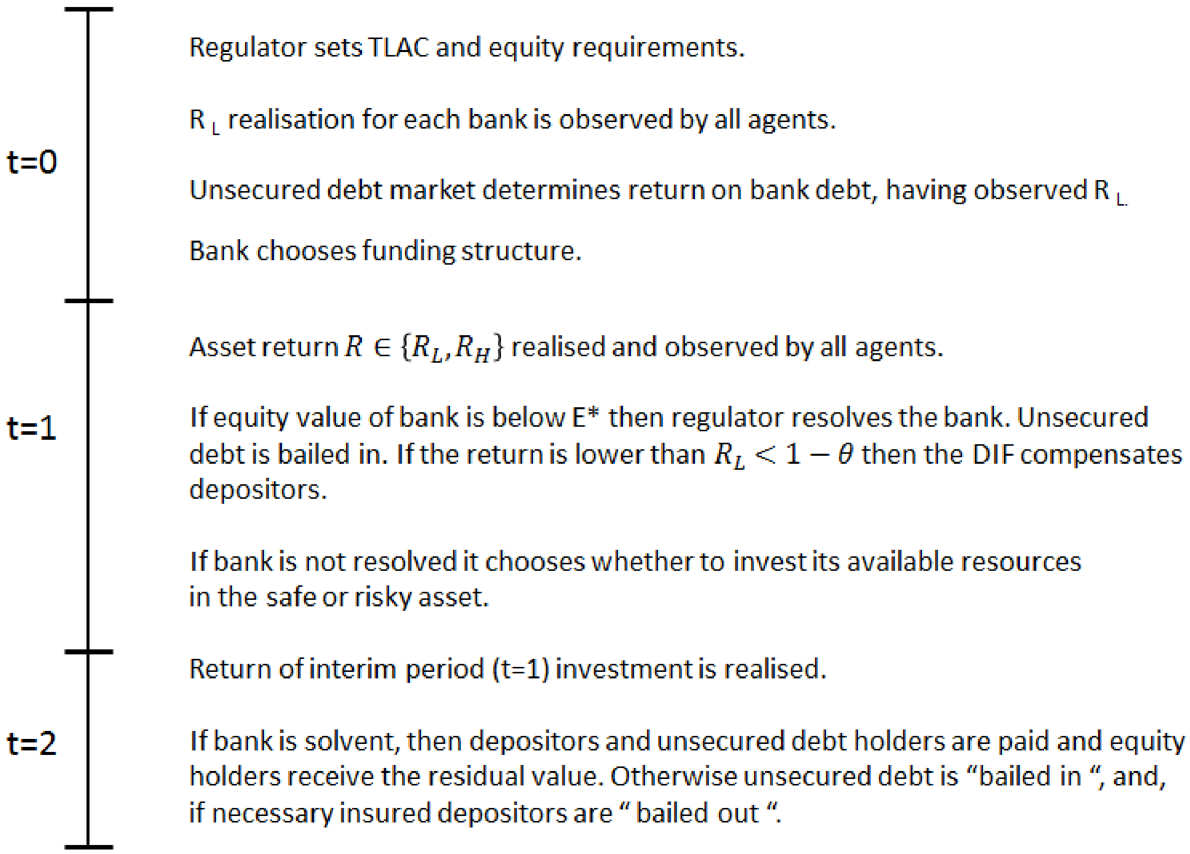
2.3 Debt repayment in the final period (t=2)

At $t = 2$, all debt is repaid if the bank is solvent, and the equity holders receive the residual return. If the bank is insolvent, insured depositors are paid in full by the DIF but the unsecured debt holders receive zero. If the bank is insolvent but the value of its assets exceed the liability to insured depositors, unsecured debt holders receive the residual return after the payment to the depositors have been made; and equity holders receive zero return.

We assume that, whilst equity is a costly means of financing banks, equity holders can absorb losses without imposing costs on the rest of the society. By contrast, we allow for the possibility that losses imposed on unsecured debt holders via a 'bail in' at $t = 1$, or at insolvency at $t = 2$, could give rise to a social cost which depends on the size of the losses that are imposed on unsecured debt holders. We allow for this possibility because unlike equity, debt will need to be rolled over. For example, Avgouleas and Goodhart (2014) and Admati and Hellwig (2015) have raised the possibility that the imposition of losses on unsecured debt holder in one bank could cause a dry-up of the market for such unsecured bank debt, especially when the financial system is already under stress. Thus, the possibility that a large-scale 'bail-in' of creditors of a systemic bank might impose negative externalities on other banks in the form of contagion cannot be ruled out. Furthermore, we also allow for the possibility that the 'bail out' of depositors might give rise to a social cost which depends on the size of losses imposed on the DIF: this captures the possibility that any DIF deficit will need to be funded by distortionary taxes which create a deadweight loss. The details of the model specification are described in Section 3.4, which examines how the regulator should set the various requirements in order to maximise the social benefits. The timing of the model is illustrated in Figure 1.

[6] For evidence of 'gambling for resurrection' during the 1990s Japanese banking crisis, see Peek and Rosengren (2005) and Nelson and Tanaka (2014).

Figure 1: Timing of the model



3 Socially optimal regulatory requirements and resolution

We now solve this model backwards in order to illustrate the determinants of the socially optimal minimum capital requirement, regulatory capital buffer and TLAC requirement. We demonstrate that *ex ante* regulatory requirements determine the share of insolvent banks in the bad state, as well as the size of the losses imposed on different stakeholders of the bank – the shareholders, the unsecured debt holders and the deposit insurance fund (DIF). Hence, the regulatory requirements will need to be set by taking into account the possible social costs associated with imposing losses on different stakeholders.

3.1 Optimal minimum capital requirement

At $t = 1$, the regulator optimally intervenes in the bank if its continuation without intervention would result in asset substitution that could magnify the eventual losses for creditors and the DIF, which also give rise to social costs. Thus, the optimal minimum capital requirement is given by the capital ratio below which the bank's shareholders have an incentive to 'gamble for resurrection'.

Since $p\gamma < 1$, a bank will always choose to reinvest in the safe asset if the macro state is 'good' and the interim return is high:

$$p\left[\gamma R_H - i\theta(1-e_0) - (1-\theta)\right] < R_H - i\theta(1-e_0) - (1-\theta) \tag{6}$$

Hence, there is no need for a regulatory intervention in a 'good' macro state when banks receive a high return.

When the realised macro state is 'bad', some banks receiving very low returns may have the incentive to invest in the risky asset if their interim returns are low, in order to 'gamble for resurrection'. This *ex post* moral hazard arises because shareholders are limitedly liable, and the interest rate on long-term debt cannot adjust once debt has been issued: thus, a bank which has received a low interim asset return can increase expected returns for shareholders at the expense of debt holders by investing in risky, negative NPV assets. More specifically, a bank has the incentive to 'gamble for resurrection' if the expected return from investing the interim return in risky asset is higher than that of investing in the safe asset:

$$p[\gamma R_L - i\theta(1-e_0) - (1-\theta)] > \max\left\{R_L - i\theta(1-e_0) - (1-\theta), 0\right\} \tag{7}$$

Rearranging the above, we obtain that banks will gamble for resurrection in the absence of any regulatory intervention if $R_L < R^T$, where R^T is defined as follows:

$$R^T \equiv \frac{1-p}{1-p\gamma}[(1-\theta) + i\theta(1-e_0)] \tag{8}$$

The investment in risky assets by a weakly capitalised bank ultimately magnifies expected losses for its creditors and the DIF (and the associated social costs), thus creating a rationale for an early intervention by the authorities to prevent asset substitution when $R_L < R^T$. It can be shown that some of these banks are still solvent. By substituting $R_L = R^T$ from (8) into (5), we obtain the minimum equity ratio below which the authorities need to intervene at $t = 1$ to prevent asset substitution by the bank (see Annex):

$$E^* = \frac{p(\gamma - 1)}{1 - p} \tag{9}$$

We interpret E^* as the optimal minimum regulatory capital requirement, or equivalently in our model, the optimal trigger for resolution. If a bank's capital ratio falls below this level, then it has the incentive to engage in socially sub-optimal asset substitution, and this creates a case for an early intervention by the authorities before the point of insolvency is reached.

3.2 Bail-in and resolution

We assume that, if the bank is found to be in breach of the minimum capital requirement (9) at $t = 1$, the regulator (or the resolution authority) will use the following decision rule:

Resolution Rule:

1. The resolution authority intervenes at $t = 1$ whenever the capital requirement is breached, i.e. whenever (5) holds, where E^* is defined by (9).
2. If there is sufficient amount of unsecured debt G that can be converted into equity to restore the bank's capital ratio to E^* or above, then convert unsecured debt into equity and let the bank continue.
3. If there is insufficient amount of unsecured debt that can be converted into equity to restore the bank's capital ratio to E^* or above, then wind down the bank. This could, for example, include transferring all, or part of failed bank's assets and liabilities to another entity. In this case, the claimholders are compensated in accordance with the claimholder hierarchy, i.e. the DIF is compensated first, followed by the unsecured debt holders, and finally the equity holders.

We assume that resolution does not destroy the value of the bank, regardless of whether the bank is successfully recapitalised through bail-in, or wound down. Rather, resolution only prevents the asset substitution (or 'gambling for resurrection') by an undercapitalised bank, and thus benefits the uninsured creditors and the DIF relative to the counterfactual of no intervention. Thus, resolution is value preserving, in the sense that it maximises the sum of the expected returns to shareholders, unsecured debt holders, depositors and the DIF, although shareholders are prevented from engaging in a profitable risk-shifting opportunity and hence are made worse off. This simplifying assumption is made in order to capture the 'no creditor worse off than liquidation' principle for resolution, as outlined in the FSB's (2015) *Principles*. Thus, it is time-consistent for the regulator to follow the Resolution Rule, as it minimises expected losses for unsecured debt holders and the deposit insurance fund, and this is consistent with minimising the social cost of bank failure. This point is explained more fully in Section 3.4.

This assumption implies that the unsecured debt holders will suffer losses only if the bank is *insolvent*, and not just in breach of the minimum capital requirement E^*, regardless of whether the bank is recapitalised or wound down, i.e.:

$$R_L < (1-\theta) + i\theta(1-e_0) \equiv R^S \tag{10}$$

Thus, if the bank is solvent at the point of resolution (i.e. $R_L \geq R^S$), then the unsecured debt holders receive their promised return $i\theta(1-e_0)$ in full. If the bank is insolvent, i.e. $R_L < R^S$, the unsecured debt holders will only receive the residual claim at wind down, given by $\max\{R_L - (1-\theta), 0\}$. The unsecured debt holders will receive nothing, although the depositors are compensated in full by the deposit insurance full when $R_L < R^D$ where:

$$R^D \equiv 1-\theta \tag{11}$$

The stakeholder payoffs and the allocation of the asset return R_L in the bad state are summarised in Table 1:

3.3 The pricing of unsecured debt

The pricing of unsecured debt G depends on the realisation of R_L *at the end* of the period $t = 0$, given the Resolution Rule as described above. Thus, the market assumes that the resolution authority will intervene at $t = 1$ whenever the minimum capital requirement is breached, and hence do not expect gambling for resurrection to occur in equilibrium. We assume that the bail-in of unsecured debt is fully credible, such that the credit risk

Table 1: Payoffs of the stakeholders in the bad state

	$R_L \in (0, R^D)$	$R_L \in (R^D, R^S)$	$R_L \in (R^S, R^T)$	$R_L \in (R^T, R^{max})$
Resolution Authority decision	Resolve	Resolve	Resolve	Don't resolve
	Stakeholder Payoffs			
Shareholders	0	0	$R_L - i\theta(1-e_0) - (1-\theta)$	$R_L - i\theta(1-e_0) - (1-\theta)$
Unsecured debt holders	0	$R_L - (1-\theta)$	$i\theta(1-e_0)$	$i\theta(1-e_0)$
Depositors	$(1-\theta)$	$(1-\theta)$	$(1-\theta)$	$(1-\theta)$
DIF	$R_L - (1-\theta)$	0	0	0

is fully priced in the interest rate i. Note that there are three *ex post* types of banks depending on the realised return R_L:

1. $0 \leq R_L \leq R^D$ (Type 1: insolvent in the low state, with zero recovery value for unsecured debt holders.)

2. $R^D \leq R_L \leq R^S$ (Type 2: insolvent in the low state, with positive recovery value for unsecured debtholders.)

3. $R^S \leq R_L \leq R^{max}$ (Type 3: solvent in the low state with full recovery value for unsecured debt holders.)

Type 1 banks will be insolvent in the low state, and the return R_L will be insufficient to cover the liability to depositors. Thus, the unsecured debt holders of Type 1 banks are paid their promised return i if $R = R_H$ which occurs with probability q and receive 0 with probability $1 - q$. The unsecured debt holders need to earn the expected return which is at least equal to the interest rate on the outside option of storage. Thus, the equilibrium interest rate for Type 1 banks' unsecured debt, denoted as i_1, is determined by the following equilibrium condition:

$$qi_1\theta(1-e_0) + (1-q)0 = \theta(1-e_0) \tag{12}$$

This yields the following interest rate which includes a risk premium to reflect the fact that unsecured debt holders only get paid their promised $i_1\theta(1-e_0)$ with probability q.

$$i_1 = \frac{1}{q} > 1 \tag{13}$$

Thus, the expected profit of Type 1 banks at the end of period $t = 0$ (net of equity holders' opportunity cost of investing in the bank) is given by:

$$\begin{aligned}\Pi_1 &= q(R_H - (1-\theta) - \frac{1}{q}\theta(1-e_0)) - \delta\theta e_0 \\ &= q\left[R_H - (1-\theta)\right] - \theta(1-e_0) - \delta\theta e_0 \end{aligned} \tag{14}$$

The private opportunity cost of equity funding enters negatively in the profit function, as equity investors only care about returns in excess of this opportunity cost. Note that the profits of Type 1 banks are distorted by the implicit subsidy from the DIF, as losses will be borne by the DIF in the bad state. It can be shown that $\frac{\partial \Pi_1}{\partial e_0} < 0$ and $\frac{\partial \Pi_1}{\partial \theta} < 0$ as long as $\delta > 1$, so Type 1 bank will issue no more equity and unsecured debt than required by the regulator at $t = 1$. As the shareholders of Type 1 banks capture positive profits in the good state while they at the most lose all their initial investments in the bad state due to limited liability, they benefit from the implicit subsidy from the deposit insurance fund.

Type 2 banks will also be insolvent in the low state, but the low return will be sufficient to cover the liability to depositors, and the unsecured debt holders will receive the residual claim in the low state. Thus, the equilibrium unsecured debt interest rate for Type 2 banks, denoted as i_2, is determined by the following condition:

$$qi_2\theta(1-e_0) + (1-q)(R_L - (1-\theta)) = \theta(1-e_0) \tag{15}$$

Thus, the interest rate on unsecured debt for Type 2 banks is given by:

$$i_2 = \frac{1}{q} - \frac{1-q}{q}\frac{R_L - (1-\theta)}{\theta(1-e_0)} \tag{16}$$

The expected profit of Type 2 banks is given by:

$$\begin{aligned}\Pi_2 &= q\left(R_H - (1-\theta) - \left(\frac{1}{q} - \frac{1-q}{q}\frac{R_L-(1-\theta)}{\theta(1-e_0)}\right)\theta(1-e_0)\right) - \delta\theta e_0 \\ &= qR_H + (1-q)R_L - (1-\theta e_0) - \delta\theta e_0 \end{aligned} \tag{17}$$

Note that, because all losses in the low state will be borne by equity and unsecured debt holders who can fully price all risks, profits of Type 2 banks are not distorted by the presence of an implicit subsidy from the DIF. Type 2 banks will also issue as much equity and unsecured debt as required by the regulator, as $\frac{\partial \Pi_2}{\partial e_0} < 0$ and $\frac{\partial \Pi_2}{\partial \theta} < 0$.

Type 3 banks will be solvent in the low state, such that the low asset return R_L will be sufficiently high to pay both depositors D and the unsecured debt holders their initial investment G in full, if the unsecured debt carries a risk free rate. This implies that the unsecured debt of Type 3 banks carries a risk free rate, such that:

$$i_3 = 1 \tag{18}$$

Thus, the expected profit of Type 3 banks is given by:

$$\begin{aligned} \Pi_3 &= q(R_H - (1-\theta) - \theta(1-e_0)) + (1-q)(R_L - (1-\theta) - \theta(1-e_0)) - \delta\theta e_0 \\ &= qR_H + (1-q)R_L - (1-\theta e_0) - \delta\theta e_0 \end{aligned} \tag{19}$$

As with type 2 banks, type 3 banks' profits are not distorted by the implicit subsidy from the DIF, as the losses are fully borne by equity holders. The expected profits are simply the expected value of the asset minus the liabilities. Type 3 banks will also issue as much equity and unsecured debt as required by the regulator, as $\frac{\partial \Pi_3}{\partial e_0} < 0$ and $\frac{\partial \Pi_3}{\partial \theta} < 0$.

Thus, for all banks, the capital buffer requirement (3) and TLAC requirement (2) are binding, such that:

$$E_0 - E^* = \theta e_0 - E^* = E^b \tag{20}$$

$$E^* + G = E^* + \theta(1-e_0) = \tau^* \tag{21}$$

The above results also imply that, if the minimum capital requirement (1) is violated at $t = 1$, then the TLAC requirement (2) is also violated. Note that, the sum of capital buffer and TLAC is equal to the private loss absorbing capacity, θ:

$$E^b + \tau^* = \theta$$

The above implies that the expected profit of a bank *at the start* of period $t = 0$ is given by:

$$\begin{aligned} E\Pi &= \int_0^{R^D} \Pi_1 f(R_L) dR_L + \int_{R^D}^{R^S} \Pi_2 f(R_L) dR_L + \int_{R^S}^{R^{maz}} \Pi_3 f(R_L) dR_L \quad (22) \\ &= \int_0^{1-\theta} \left\{ q\left[R_H - (1-\theta)\right] - \theta(1-e_0) \right\} f(R_L) dR_L \\ &+ \int_{1-\theta}^{R^{max}} \left\{ qR_H + (1-q)R_L - (1-\theta e_0) \right\} f(R_L) dR_L - \delta\theta e_0 \end{aligned}$$

3.4 Ex ante social welfare

The capital buffer and TLAC requirements, E^b and τ^*, will determine the share of each type in the banking sector when the bad macro state – or a system-wide stress – materialises *ex post*. Thus, we now consider how these two regulatory requirements are optimally set, when the optimal minimum capital requirement E^* is determined by (9). In order to pin down interior solutions for E^b and τ^*, we make the following assumptions in writing the social welfare function:

Assumption 1 (loss-absorbing equity): Equity can absorb losses *ex post* without imposing a social cost.

Assumption 2 (ex post costly bail-in): The imposition of losses on the holders of unsecured debt that arise is associated with a social deadweight loss $\psi(L_{G,T})$ that are increasing and convex in the loss given default $L_{G,T}$ imposed on unsecured debt holders of Type T bank in the bad state (where $T \in \{1, 2\}$), so that $\psi(0) = 0$, $\psi(L_{G,T}) \geq 0$ $\forall L_{G,T} > 0$, $\psi'(L_{G,T}) > 0$, $\psi''(L_{G,T}) > 0$.

Assumption 3 (ex post costly bail-out): The imposition of losses on the deposit insurance fund (DIF) are associated with a social deadweight loss $\chi(L_{D,1})$ that is increasing and convex with respect to the loss given default $L_{D,1}$ imposed on the DIF at resolution (for Type 1 banks), where $\chi(0) = 0$, $\chi(L_{D,1}) \geq 0$ $\forall L_{D,1} > 0$, $\chi'(L_{D,1}) > 0$, and $\chi''(L_{D,1}) > 0$.

Assumption 4 (value-preserving resolution): The resolution of a failing bank will not destroy the recovery value of its assets, R_L, which will be distributed amongst the claimholders according to hierarchy. The resolution is triggered whenever $E < E^*$.

Assumption 4 implies that all of the bank's asset returns are captured by a combination of its shareholders, the unsecured debt holders, and the DIF at resolution. This assumption is made purely for expositional simplicity. We expect that dropping this assumption would simply increase the optimal capital buffer by increasing the cost of bail-in and bail-out. Assumptions 1-3 imply that the imposition of a given loss on unsecured debt holders or the DIF is socially more costly than the imposition similarly sized loss on equity holders, and that the social cost of a bank failure is captured by the externalities caused by the bail-in and bail-out. As discussed in Section 2, the externalities from bail-in (Assumption 2) could arise from the fact that, unlike equity, debt needs to be rolled over: thus, there is a risk that the imposition of losses on unsecured debt holders of one bank gives rise to 'contagion externalities' by raising concerns about the solvency of other banks and creating difficulties for them to roll over over their maturing unsecured debt. This possibility is of particular concern when the market is already under stress and there is a generalised concern about the stability of the banking system as a whole. We assume that the social deadweight loss from bail-in, $\psi(L_{G,T})$, is convex, thus capturing the possibility that, while a small scale bail-in is done relatively easily without causing contagion, large scale bail-in is more likely to create investor uncertainty across the banking sector.

Assumption 3 implies that the imposition of losses on the DIF is also associated with a social cost. We interpret this as a deadweight loss associated with funding any deficit of the DIF via distortionary taxes. For completeness, however, we do consider in Section 3.5 the cases in which Assumptions 2 and 3 are dropped.

Since capital buffer and TLAC requirements are binding, as in (20) and (21), setting E^b and τ^* amounts to selecting the socially optimal θ and e_0, subject to resolution occurring whenever the equity ratio falls below E^* (given by (9)) at $t = 1$. Thus, the regulator sets these parameters to maximise the social welfare, denoted as W, which is given by the expected return on investment of ex-ante identical banks – which is equal to the sum of the expected payoffs of equity investors, uninsured creditors, depositors and the deposit insurance fund – net of the social opportunity cost of equity funding and the expected social costs of bail in and bail out (see Annex for derivation):

$$
\begin{aligned}
W &\equiv \bar{R} - \delta_s \theta e_0 \qquad (23) \\
&- (1-q)\left(\int_{R^D}^{R^S(i=i_3)} \psi(L_{G,2}) f(R_L) dR_L + \int_0^{R^D} \left[\psi(L_{G,1}) + \chi(L_{D,1})\right] f(R_L) dR_L\right)
\end{aligned}
$$

where

$$
\begin{aligned}
\bar{R} &\equiv qR_H + (1-q)\int_0^{R^{max}} R_L f(R_L) dR_L \\
\delta_s &\equiv \delta - 1 \\
L_{G,1} &\equiv i_1\theta(1-e_0) \qquad (24) \\
L_{G,2} &\equiv i_2\theta(1-e_0) - [R_L - (1-\theta)] \qquad (25) \\
L_{D,1} &\equiv (1-\theta) - R_L \qquad (26)
\end{aligned}
$$

and, using (10), (18), the point of insolvency can be expressed as:

$$
R^S(i = i_3) = (1-\theta) + \theta(1-e_0) = 1 - \theta e_0 \qquad (27)
$$

As explained in Section 2.1, δ_s in (23) reflects the *social* opportunity cost of equity funding, which captures the higher (deadweight) transaction. The derivation of the social welfare function (23) is in the Annex.

It is worth clarifying at this point what the social costs and benefits of increasing the capital buffer are in our model. In our model, increasing the capital buffer reduces both the probability of a bank failure (by lowering the point of insolvency, (27)) and the cost of a bank failure (by lowering the losses imposed on unsecured debt holders, (24) and (25)). But this comes at the cost of reducing output by 'crowding out' investments in other sectors that banks' equity investors could have funded instead. Note that, in the absence of social deadweight costs associated with bank failures ($\psi(.) = 0$ and $\chi(.) = 0$), the regulator simply maximises the expected total return of the bank – which will be shared amongst all claimholders – net of the social cost of equity funding.

3.5 Determinants of optimal regulatory requirements

We now examine the key determinants of the socially optimal capital buffer E^b and TLAC requirement τ^*, given the optimal minimum requirement E^* given by (9), through numerical simulations of (9) and (23). To do this, we assume the following quadratic functional forms for the social costs of bail-in and bail-out:

$$\begin{aligned} \psi(L_{G,T}) &= \lambda_G L_{G,T} + \tilde{\lambda}_G L_{G,T}^2 \\ \chi(L_{D,T}) &= \lambda_D L_{D,T} + \tilde{\lambda}_D L_{D,T}^2 \end{aligned}$$

The derivation of the social welfare function under these assumptions is provided in the Annex. Under the baseline calibration, we assume the following: $p = 0.3$, $\gamma = 1.14$, $R_H = 2$, $R^{\max} = 1.045$, $\delta_s = 0.0025$, $\lambda_G = 0.02$, $\tilde{\lambda}_G = 0.0256$, $\lambda_D = 0.023$, $\tilde{\lambda}_D = 0.0089$, $q = 0.9$. The baseline parameterisations are chosen purely to reproduce the minimum TLAC, minimum capital and capital buffer requirements as set out by the Financial Stability Board (FSB) and Basel Committee on Banking Supervision (BCBS). As these parameters are not chosen based on empirical estimates, we are primarily interested in the directional (rather than quantitative) change in the optimal trio of regulatory requirements caused by the changes in the assumptions about the key parameters. But we note that the baseline parameterisations reflect the view that the social cost of equity funding is small, and that the cost of bail-in is smaller than the cost of bail-out as long as the size of loss at insolvency is relatively small.

The tables below summarise the results from numerical simulation. The third column of Table 2 below shows the optimal regulatory requirements under the baseline calibration: in this scenario, we obtain an optimal minimum capital requirement of 6.0% (consistent with Basel III end-point Tier 1 capital ratio), capital buffer of 5.0% (consistent with Basel III end-point capital conservation buffer of 2.5% plus G-SIB buffer of 1-2.5%), and TLAC of 18.0% (consistent with the full implementation of the FSB (2015)'s *Principles* in 2022).

A key unknown parameter is the cost of bail-in, given that there is little historical precedents for orderly imposition of losses on private bond holders of large banks. In the fourth column of Table 2, we present the 'low bail in cost' scenario, in which $\tilde{\lambda}_G = 0.02$: i.e. the bail-in cost is both lower and less convex than in the baseline. The optimal equity buffer falls in this case to 4%, while the optimal TLAC rises to 21%. This is because in this scenario, bail-in is lower cost than bail-out, and unsecured debt is a close substitute to equity in its ability to absorb losses without creating large externalities. Conversely, a higher and more convex bail-in cost ($\tilde{\lambda}_G = 0.03$, shown in the fifth column of Table 2) would imply a lower optimal TLAC (16.5%) and a higher capital buffer (5.6%) than the baseline. Note that the minimum capital requirement is invariant to the cost of bail-in, as this is determined by the need to ensure that the bank has enough 'skin in the game' to incentivise it to invest in the safe asset.

Table 2: Optimal regulation and sensitivity to bail-in costs

	Expression	Baseline	Low bail-in cost	High bail-in cost
Minimum Capital Ratio	E^*	6.0%	6.0%	6.0%
TLAC	$\tau*$	18.0%	21.0%	16.5%
Capital buffer	E^b	5.0%	4.0%	5.6%
Minimum TLAC + Capital Buffer	θ	23.0%	25.0%	22.0%

Bail-out costs also matter. In the 'low bail-out cost' scenario presented in column 4 of Table 3 (in which $\tilde{\lambda}_D = 0.008$), both the capital buffer (3.8%) and TLAC (17.2%) are lower than the baseline (shown in column 3). Conversely, in the 'high bail-out cost' scenario (shown in column 5) in which $\tilde{\lambda}_D = 0.0095$, so that bail-out costs are both higher and more convex, both the capital buffer (5.9%) and TLAC (18.6%) can be considerably higher relative to the baseline.

Table 3: Optimal regulation and sensitivity to bail-out costs

	Expression	Baseline	Low bail-out cost	High bail-out cost
Minimum Capital Ratio	E^*	6.0%	6.0%	6.0%
TLAC	τ^*	18.0%	17.2%	18.6%
Capital buffer	E^b	5.0%	3.8%	5.9%
Minimum TLAC + Capital Buffer	θ	23.0%	21.0%	24.5%

There are also other important parameters that determine the optimal regulatory ratios, as shown in Table 4. For example, a higher social cost of equity ($\delta_s = 0.00255$)

Table 4: Optimal regulation under different scenarios

	Baseline	High equity cost	Strong gambling incentive	Higher macro risk
Minimum Capital Ratio	6.0%	6.0%	6.4%	6.0%
TLAC	18.0%	18.1%	18.4%	17.3%
Capital buffer	5.0%	3.4%	4.6%	8.7%
Minimum TLAC + Capital Buffer	23.0%	21.5%	23.0%	26.0%

would imply that the regulator should require banks to hold a lower capital buffer than the baseline (column 3 in Table 4). Interestingly, stronger incentives for failing banks to engage in gambling, or asset substitution ($\gamma = 1.15$, shown in column 4 in Table 4) implies that the regulator should set a higher minimum capital requirement, but also a lower capital buffer and a higher TLAC requirement, so as to maintain the sum of TLAC and capital buffer (θ) the same as in the baseline: this is intuitive, as the cost of insolvency is unchanged from the baseline, while the need for early intervention has increased. Finally, if the probability of adverse macro shock becomes higher ($q = 0.895$, column 5 in Table 4), then the capital buffer should be increased while the TLAC requirement can be reduced. This reflects the higher expected social cost of bank failure, which calls for a higher capital and lower unsecured debt to reduce the probability of bank failure. This analysis raises an interesting possibility that, as the capital buffer is raised with increased risk of system wide distress, the TLAC requirement could be *reduced* to allow banks to fund themselves with more capital and less debt. We note, however, that our analysis has not considered the possibility that a minimum level of bail-in debt is needed in order to ensure that bail-in itself is credible. If this is indeed the case, then it may not be desirable to vary the TLAC requirement with the countercyclical capital buffer in practice.

For completeness, we also examine the extreme case in which both bail-out and bail-in are costless ($\lambda_D = \lambda_G = 0$ and $\tilde{\lambda}_D = \tilde{\lambda}_G = 0$): thus, our Assumptions 2 and 3 are dropped, and both deposits and debt become perfect substitutes to equity as loss-absorbing instruments. In this case, while a minimum capital requirement E^* is still needed in order to prevent *ex post* moral hazard, and there is no need for a capital buffer or TLAC requirement. In the next section, we demonstrate that, when *ex ante* moral hazard is present, then the regulator should still require that the bank has sufficient private loss absorbing capacity, θ.

We also study what happens if only Assumption 2 is dropped. Suppose that bail-in is costless ($\lambda_G = \tilde{\lambda}_G = 0$) but bail-out remains costly (as in the baseline). In this case, it is optimal to require banks to meet a TLAC requirement of 100% and a minimum capital requirement of E^* (=6% as in the baseline), but there will be no need for a capital buffer. This is intuitive: if bail-in is costless, then unsecured debt and equity are perfect substitutes *ex post* as loss absorbing instruments, and hence unsecured debt is favoured over equity as the latter is socially more costly *ex ante*. Deposits are socially less desirable than unsecured debt in this case. We note, however, that deposits may carry benefits that are not considered in this model, such as the convenience of on-demand withdrawal, such that a 100% TLAC requirement may not be desirable even when bail-in is costless. Finally, we note that, when $\delta_s = 0$, our model suggests that bank should be fully funded by equity.

4 Ex-ante moral hazard and the impact of regulatory policies

Thus far, we have assumed that the probability of a high return, q, is exogenous. In this section, we assume that q is determined endogenously by banks' decisions over the monitoring of their projects, which requires them to exert costly effort. We then examine how ex-ante regulation affects the incentive to monitor.

Suppose that, in the absence of any monitoring by banks at $t = 0$, the probability of the project yielding high return is q_L. Following Holmstrom and Tirole (1997), suppose that, if banks choose to exert a monitoring effort which has private cost C, they can increase the probability of project success from q_L to q_H, where $q_H > q_L$. We assume that the bank chooses the monitoring effort *at the end of* $t = 0$, after the realisation of R_L has been observed. At this point there is no information asymmetry between banks and potential unsecured debt holders, so the market can fully infer banks' monitoring effort and therefore price in the risk depending on whether or not the bank monitors its investment at t=0.

4.1 Socially efficient monitoring

Monitoring is socially efficient for Type 1 banks with $R_L \in (0, R^D)$, if the following condition holds:

$$\begin{aligned} q_H R_H + (1-q_H)\left[R_L - \psi(L_{G,1}) - \chi(L_{D,1})\right] - C &\geq \\ q_L R_H + (1-q_L)\left[R_L - \psi(L_{G,1}) - \chi(L_{D,1})\right], \forall R_L &\in (0, R^D) \end{aligned} \tag{28}$$

In other words, the private monitoring cost C incurred by the banks must be sufficiently small relative to the social costs of bail in and bail out. This can be simplified to:

$$C \leq C_1^* \equiv (q_H - q_L)(R_H - R_L) + (q_H - q_L)[\psi(L_{G,1}) + \chi(L_{D,1})], \forall R_L \in (0, R^D) \tag{29}$$

The right hand side is the sum of the marginal benefits from monitoring that accrue to banks' claimholders, $(q_H - q_L)(R_H - R_L)$, and to the society in the form of reduced externalities from bail ins and bail outs, $(q_H - q_L)[\psi(L_{G,1}) + \chi(L_{D,1})]$.

Similarly, monitoring is efficient for Type 2 banks with $R_L \in (R^D, R^S)$, as long as:

$$q_H R_H + (1-q_H)\left[R_L - \psi(L_{G,2})\right] - C \geq q_L R_H + (1-q_L)\left[R_L - \psi(L_{G,2})\right], \forall R_L \in (R^D, R^S)$$

This can be reorganised as:

$$C \leq C_2^* \equiv (q_H - q_L)(R_H - R_L) + (q_H - q_L)\psi(L_{G,2}), \forall R_L \in (R^D, R^S) \tag{30}$$

Finally, monitoring is efficient for Type 3 banks with $R_L \in (R^S, R^{\max})$, as long as:

$$q_H R_H + (1-q_H)R_L - C \geq q_L R_H + (1-q_L)R_L, \forall R_L \in (R^S, R^{\max})$$

This can be reorganised as:

$$C \leq C_3^* \equiv (q_H - q_L)(R_H - R_L), \forall R_L \in (R^S, R^{\max}) \tag{31}$$

In what follows, we assume that $C \leq C_1^*$, $C \leq C_2^*$, and $C \leq C_3^*$ for all Types 1, 2, and

3 banks, respectively. In other words, the regulator would always want to ensure that banks monitor their projects.

4.2 Private monitoring incentives

We now consider the monitoring incentives of a bank which seeks to maximise shareholder returns in a context in which monitoring is socially desirable. From previous analysis in Section 3.3, we know that profits of Type 1 banks are distorted by the presence of implicit subsidy from the DIF. Below, we demonstrate that only Type 1 banks are therefore prone to *ex ante* moral hazard; and that having a sufficiently high private loss absorbing capacity, θ, which is the sum of TLAC plus equity buffer, can help reduce this.

For Type 1 banks with $R_L \in (0, R^D)$, unsecured debt has zero recovery value if $R = R_L$. From (13), we know that the interest rate on unsecured debt is $\frac{1}{q_H}$ if the bank chooses to monitor, and $\frac{1}{q_L}$ if it decides not to monitor, such that $\frac{1}{q_H} < \frac{1}{q_L}$. Type 1 banks will monitor as long as the expected profit from monitoring, net of monitoring costs, exceed the expected profit of not monitoring:

$$\Pi_1(q_H) - C > \Pi_1(q_L) \tag{32}$$

where $\Pi_1(.)$ is given by (14). Reorganising the above, we can show that Type 1 banks will monitor their projects as long as $\theta \geq \theta^*$where:

$$\theta^* = \frac{C}{q_H - q_L} - R_H + 1 \tag{33}$$

This shows that, unless θ is sufficiently high, Type 1 banks will be subject to moral hazard and will not monitor their project. Thus, the regulator can ensure that Type 1 banks take actions to reduce risks by setting θ – TLAC *plus* equity buffer – above θ^*. We emphasise that the incentive to engage in moral hazard is influenced by the total amount of losses that can be absorbed by private claimholders as opposed to taxpayers. In particular, the monitoring incentives are unaffected by the split of θ between equity and unsecured debt, as unsecured debt prices in the risks that banks are taking. Thus, as long as θ is sufficiently high, distortions in monitoring effort arising from a limitedly liable bank being funded by insured deposits is eliminated.[7]

For instance, for baseline parameterisations $C = 0.45$, $q_H = 0.9$, $q_L = 0.5$ and $R_H = 2$, $\theta \geq \theta^* =$12.5% is needed to induce monitoring by Type 1 banks. But if there is an exogenous shock that reduces the probability of a high return that banks can achieve through monitoring, θ will need to be raised in order to induce monitoring: for instance, for $q_H = 0.89$, $\theta \geq \theta^* =$15.4% is needed to induce monitoring by Type 1 banks, consistent with our previous analysis. Note that the optimal θ – which maximises social welfare (23) – could be higher than the minimum required to induce monitoring by Type 1 banks.

For Type 2 banks with $R_L \in (R^D, R^S)$ and Type 3 banks $R_L \in (R^S, R^{\max})$, we have already seen that their profits are not distorted by the presence of the guarantee on deposits, because the DIF will not have to pay out anything even in the bad scenario. Type 2 banks will monitor as long as:

$$\Pi_2(q_H) - C > \Pi_2(q_L)$$

where $\Pi_2(.)$ is given by (17). Similarly, Type 3 banks with $R_L \in (R^S, R^{\max})$ will monitor as long as:

$$\Pi_3(q_H) - C > \Pi_3(q_L)$$

where $\Pi_3(.)$ is given by (19). Reorganising the above, it can be shown that both Type 2 and Type 3 banks will choose to monitor as long as:

$$C < (q_H - q_L)(R_H - R_L)$$

The right hand side is the benefits of monitoring that accrue to the banks' claimholders. Comparing the above with (30) and (31), it is clear that Type 3 have the socially optimal incentive to monitor, regardless of the level of θ. This is because Type 3 banks will remain solvent even in the bad state, so that all costs and benefits are internalised. By contrast, Type 2 banks have a sub-optimal incentive to monitor, if $(q_H - q_L)(R_H - R_L) < C < C_2^*$: if so, Type 2 banks do not have the incentive to monitor, because the private cost of monitoring outweighs the benefit, even though it is socially optimal for them to

[7] Or equivalently the distortion created from risk-insensitive interest rates on insured deposits is sufficiently small.

monitor once the cost of bail in is taken into consideration. Note that Type 2 banks' incentive to monitor is independent of θ, because they will not impose losses on the DIF even in the bad state and hence are not subject to moral hazard driven by the implicit subsidy. This is why *ex ante* regulatory requirements cannot induce them to monitor, if $(q_H - q_L)(R_H - R_L) < C < C_2^*$.

5 Conclusion

The interactions between the new regulatory requirements on banks, which were introduced after the global financial crisis of 2007-2008, is still a relatively unexplored area. In this context, our paper makes two key contributions. First, we clarify within a simple framework what factors determine the optimal settings of the trio of regulatory requirements: the minimum capital requirement, the TLAC requirement, and the capital buffer. Second, we show which of the trio of the regulatory requirements should be adjusted cyclically.

Our analysis illustrates that the optimal size of the capital buffer and TLAC, and the optimal composition of TLAC, depend on the social cost of a crisis (i.e. the costs of bail-in and bail-out), as well as the probability of a system-wide shock. This implies that the policymakers will need to take a view on how costly they expect bail-in – which is yet to be tested – to be. If they expect system-wide externalities from bail-in to be limited, then setting a low capital buffer and a high TLAC requirement would be optimal, when equity funding is socially expensive. By contrast, if policymakers fear that bail-in could potentially cause contagion, or would be subject to high legal costs, then a relatively low TLAC requirement and a high capital buffer would be desirable.

Our analysis also raises an interesting possibility that it may be desirable to make TLAC as well as capital buffer time-varying: in particular, as the risk of system-wide shock increases, the capital buffer should be raised and TLAC should be reduced in order to reduce the probability of bank insolvency. This result could alternatively be interpreted as stating that forbearance on the minimum TLAC requirement could be justifiable if the bank in question is well capitalised, and that such a policy may not give rise to the same adverse incentives associated with forbearance on the minimum capital requirement. This result arises directly from the assumption that bail-in is always credible regardless of the amount of bail-in debt, and hence bail-in debt is a perfect substitute to equity in preventing ex ante moral hazard. We note, however, that our simple theoretical model does not incorporate the possibility that a minimum level of TLAC might be needed in order to make bail-in itself credible. If that is indeed the case, then forbearance on on TLAC, or making TLAC time-varying, would not be be desirable in practice as it could undermine the credibility of bail-in itself.

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A Annex

A.1 Minimum Capital Requirement

The minimum capital requirement is obtained by substituting the gambling threshold $R_L = R^T$ from(8) into (5). Rearranging (5) we obtain $R_L = \frac{1-\theta+i\theta(1-e_0)}{1-E^*}$. Thus the minimum capital requirement E^* solves the following condition:

$$\frac{1-\theta+i\theta(1-e_0)}{1-E^*} = \frac{1-p}{1-p\gamma}[(1-\theta)+i\theta(1-e_0)] \tag{34}$$

which becomes

$$1-E^* = \frac{1-p\gamma}{1-p}$$

Rearranging the above, we obtain (9).

A.2 Derivation of the social welfare function

To derive (23), note that the social welfare consists of two components: i) the expected return from banks' investment (which are divided between their claimholders) net of the social opportunity cost of funding that investment, and ii) the expected social cost of bank failure. by:

$$\begin{aligned}
\text{Expected return on investment net of funding cost} &= \bar{R} - (1-\theta) - \theta(1-e_0) - \delta\theta e_0 \\
&= \bar{R} - 1 - (\delta - 1)\theta e_0 \\
&= \bar{R} - \delta_s \theta e_0 - 1
\end{aligned} \tag{35}$$

where $\bar{R} \equiv qR_H + (1-q)\int_0^{R^{max}} R_L f(R_L) dR_L$ is the expected return on banks' investment (which is the sum of the expected payoffs of the bank's shareholders, uninsured creditors, depositors and the deposit insurance fund), and $\delta_s \equiv \delta - 1$ is the social opportunity cost of funding the bank with equity instead of debt or deposits.

The second part of the social welfare function is given by the expected cost of bank failure, which arises in a bad state when the bank becomes insolvent:

$$\text{Expected social cost} = -(1-q) \Big(\int_{R^D}^{R^S(i=i_3)} \psi(L_{G,2}) f(R_L) dR_L + \int_0^{R^D} \left[\psi(L_{G,1}) + \chi(L_{D,1})\right] f(R_L) dR_L \Big) \quad (36)$$

where losses imposed on uninsured debt holders and depositors of Type 1 and Type 2 banks are given by:

$$\begin{aligned} L_{G,1} &\equiv i_1\theta(1-e_0) \\ L_{G,2} &\equiv i_2\theta(1-e_0) - [R_L - (1-\theta)] \\ L_{D,1} &\equiv (1-\theta) - R_L \end{aligned}$$

and, using (10), (18), the point of insolvency can be expressed as:

$$R^S(i = i_3) = (1-\theta) + \theta(1-e_0) = 1 - \theta e_0$$

Summing up (35) and (36) after dr opping the constant -1, we obtain (23).

A.3 Social welfare function used for numerical simulation

We now derive the specific functional form of the welfare function (23), under the following two assumptions.

$$\begin{aligned} \psi(L_{G,T}) &= \lambda_G L_{G,T} + \tilde{\lambda}_G L_{G,T}^2 \\ \chi(L_{D,1}) &= \lambda_D L_{D,T} + \tilde{\lambda}_D L_{D,T}^2 \end{aligned}$$

In this case, (23) can be rewritten in the following form:

$$W = \bar{R} - (X + \tilde{X}) - (Y + \tilde{Y}) - \delta_s \theta e_0 \quad (37)$$

where:

$$
\begin{aligned}
X &= (1-q)\lambda_G \int_{1-\theta}^{1-\theta e_0} L_{G,2} f(R_L)\, dR_L \\
\tilde{X} &= (1-q)\tilde{\lambda}_G \int_{1-\theta}^{1-\theta e_0} L_{G,2}^2 f(R_L)\, dR_L \\
Y &= (1-q) \int_0^{1-\theta} (\lambda_G L_{G,1} + \lambda_D L_{D,1})\, f(R_L) \\
\tilde{Y} &= (1-q) \int_0^{1-\theta} \left(\tilde{\lambda}_G L_{G,1}^2\right) f(R_L)
\end{aligned}
$$

Expanding the above:

$$
\begin{aligned}
\bar{R} &= qR^H + (1-q) \int_0^{R^{\max}} R_L f(R_L) dR_L \\
&= qR^H + (1-q)\frac{R^{\max}}{2}
\end{aligned}
$$

The losses suffered by unsecured debt holders of Type 1 and 2 banks in the event of insolvency are given by:

$$
L_{G,1} = i_1\theta(1-e_0) = \frac{\theta(1-e_0)}{q}
$$

$$
\begin{aligned}
L_{G,2} &= i_2\theta(1-e_0) - (R_L - (1-\theta)) \\
&= \left(\frac{1}{q} - \frac{1-q}{q}\frac{R_L-(1-\theta)}{\theta(1-e_0)}\right)\theta(1-e_0) - (R_L - (1-\theta)) \\
&= \frac{1}{q}(1-\theta e_0 - R_L)
\end{aligned}
$$

Substituting the above:

$$
\begin{aligned}
X &= \frac{(1-q)\lambda_G}{qR^{\max}} \int_{1-\theta}^{1-\theta e_0} \left[(1-\theta e_0 - R_L)\right] dR_L \\
&= \frac{(1-q)\lambda_G}{qR^{\max}} \left[\left[(1-\theta e_0)\, R_L\right]_{1-\theta}^{1-\theta e_0} - \left[\frac{R_L^2}{2}\right]_{1-\theta}^{1-\theta e_0} \right] \\
&= \frac{(1-q)\lambda_G}{qR^{\max}} \left[(1-\theta e_0)\left((1-\theta e_0) - (1-\theta)\right) - \frac{1}{2}\left[(1-\theta e_0)^2 - (1-\theta)^2\right] \right] \\
&= \frac{(1-q)\lambda_G}{qR^{\max}} \left[\theta\,(1-\theta e)\,(1-e_0) - \frac{1}{2}\left[(1-\theta e_0)^2 - (1-\theta)^2\right] \right]
\end{aligned}
$$

$$
\begin{aligned}
\tilde{X} &= \frac{(1-q)\tilde{\lambda}_G}{R^{\max}} \int_{1-\theta}^{1-\theta e_0} \left(\frac{1}{q}(1-\theta e_0 - R_L)\right)^2 dR_L \\
&= \frac{(1-q)\tilde{\lambda}_G}{q^2 R^{\max}} \int_{1-\theta}^{1-\theta e_0} \left[(1-\theta e_0)^2 - 2R_L(1-\theta e_0) + R_L^2\right] dR_L \\
&= \frac{(1-q)\tilde{\lambda}_G}{q^2 R^{\max}} \left\{ (1-\theta e_0)^2[(1-\theta e_0) - (1-\theta)] - (1-\theta e_0)[(1-\theta e_0)^2 - (1-\theta)^2] + \frac{[(1-\theta e_0)^3 - (1-\theta)^3]}{3} \right\} \\
&= \frac{(1-q)\tilde{\lambda}_G}{q^2 R^{\max}} \left\{ \theta(1-\theta e_0)(1-\theta)(e_0-1) + \frac{[(1-\theta e_0)^3 - (1-\theta)^3]}{3} \right\}
\end{aligned}
$$

$$
\begin{aligned}
Y &= (1-q) \int_0^{1-\theta} \left[\lambda_G \frac{\theta(1-e_0)}{q} + \lambda_D\left((1-\theta) - R_L\right) \right] f\left(R_L\right) dR_L \\
&= \frac{(1-q)}{R^{\max}} \left[\left(\lambda_G \frac{\theta(1-e_0)}{q} + \lambda_D(1-\theta) \right) R_L \right]_0^{1-\theta} - \frac{(1-q)\lambda_D}{R^{\max}} \left[\frac{R_L^2}{2}\right]_0^{1-\theta} \\
&= \frac{(1-q)}{R^{\max}} \left[\left(\lambda_G \frac{\theta(1-e_0)}{q} + \lambda_D(1-\theta) \right)(1-\theta) - \lambda_D \frac{(1-\theta)^2}{2} \right] \\
&= \frac{(1-q)}{R^{\max}} \left[\left(\lambda_G \frac{\theta(1-\theta)(1-e_0)}{q} \right) + \lambda_D \frac{(1-\theta)^2}{2} \right]
\end{aligned}
$$

$$
\begin{aligned}
\tilde{Y} &= \frac{(1-q)}{R^{\max}} \int_0^{1-\theta} \left[\tilde{\lambda}_G \left(\frac{\theta(1-e_0)}{q} \right)^2 \right] dR_L \\
&= \frac{(1-q)\tilde{\lambda}_G}{R^{\max}} \left(\frac{\theta(1-e_0)}{q} \right)^2 (1-\theta)
\end{aligned}
$$