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Equity versus Bail-in Debt  
in Banking:  
An Agency Perspective

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# Equity versus Bail-in Debt in Banking: An Agency Perspective

## Abstract

We examine the optimal size and composition of banks' total loss absorbing capacity (TLAC). Optimal size is driven by the trade-off between providing liquidity services through deposits and minimizing deadweight default costs. Optimal composition (equity vs. bail-in debt) is driven by the relative importance of two incentive problems: risk shifting (mitigated by equity) and private benefit taking (mitigated by debt). Our quantitative results suggest that TLAC size in line with current regulation is appropriate. However, an important fraction of it should consist of bail-in debt because such buffer size makes the costs of risk-shifting relatively less important at the margin.

JEL Codes: G21, G28, G32.

Keywords: Bail-in debt, loss absorbing capacity, risk shifting, agency problems, bank regulation.

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# 1 Introduction

The capital deficits revealed among banks during the 2007-2009 global financial crisis and the goal to prevent tax payers from having to bail out the banks in a future crisis have led to an unprecedented reinforcement in banks' loss-absorbing capacity. Specifically, Basel III has increased the minimum Tier 1 capital requirement first from 4% to 6% (since 2015) and then to 8.5% (from 2019, once the so-called capital conservation buffer gets fully loaded). In addition, the Financial Stability Board (FSB, 2015) has recently stipulated that global systemically important banks should have 'Total Loss-Absorbing Capacity' (or TLAC) equal to 16% of risk weighted assets (RWA) from January 2019 and up to 18% of RWA since 2022. Policy makers expect a significant fraction of such TLAC to come from liabilities other than common equity. Accordingly, liabilities such as so-called bail-in debt will be first to absorb losses after equity is wiped out and before a bank receives any support from resolution funds, deposit insurance schemes or taxpayers.

The introduction of TLAC requirements aims to enhance the credibility of commitments to minimize public support to banks during crises and to increase market discipline. However, relatively little analysis exists on whether it should be satisfied with equity or with bail-in debt, and more generally on banks' optimal level and composition of loss-absorbing liabilities. In this paper we study these issues in the context of a model in which the choice between equity and bail-in debt is driven by their impact on the incentives of bank insiders.

Banks in our framework are run by specialist insiders (bankers, bank managers) who take two types of hidden actions under limited liability. The first is a standard unobservable risk shifting choice while the second is a choice of how much private benefits to extract at a cost in terms of the overall revenues of the bank. We consider a situation in which insiders' monetary incentives are determined by the payoffs of their equity stakes at the bank and, hence, in which the bank's capital structure (i.e. the combination of liabilities through which funding is raised among outside investors) is initially decided taking into account its subsequent impact on insiders' incentives.<sup>1</sup> As is standard in the literature, the risk shifting incentives

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<sup>1</sup>This description implies abstracting from the potential conflict of interest between the equityholders who

are minimized by choosing an equity heavy capital structure (Jensen and Meckling, 1976). In contrast, excessive private benefit taking can be minimized by giving a large equity stake to insiders and raising all the outside funding in the form of debt (Innes, 1990).

In order to provide richer (and more quantitatively relevant) predictions for banks' capital structure, we consider some additional departures from the ideal conditions of Modigliani-Miller. First, we assume that, differently from bail-in debt, insured deposits provide a liquidity convenience yield to investors, so that, other things equal, they are cheaper than bail-in debt.<sup>2</sup> Second, we assume that default on insured deposits (or, equivalently, causing losses to the deposit insurance agency, DIA) involves deadweight costs larger than causing equivalent losses to the holders of bail-in debt. So bail-in debt in the model is simply uninsured debt which is junior to insured deposits, provides no especial liquidity services to its holders, and implies lower deadweight losses in case of default.<sup>3</sup> For realism, the model also includes corporate taxes levied on banks' positive earnings after interest.

The model implies a socially optimal capital structure that is driven by two main trade-offs. First, a regulator interested in maximizing the net social surplus generated by banks would like to set the size and composition of TLAC (equity plus bail-in debt) in order to trade off expected deadweight costs of defaulting on deposits against the liquidity services provided by deposits. As a protection against costly default on deposits, bail-in debt and equity are perfect substitutes. However, they differ strongly in their impact on incentives. This leads to the second key trade off faced by the regulator: the one between controlling risk shifting (for which outside equity is superior) and preventing excessive private benefit taking (for which bail-in debt dominates).

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control the bank through its board of directors and the managers whose incentives are shaped by a variety of explicit and implicit incentives schemes, including monetary compensation, stock, stock options, dismissal threats, etc. So our insiders can be thought of as the coalition between controlling equityholders and the bank's managers.

<sup>2</sup>The liquidity role of bank deposits is microfounded by Diamond and Dybvig (1983) and plays a key role in the assessment of capital regulation provided by Van den Heuvel (2008) and Begenau (2015), among others.

<sup>3</sup>Specifically, in the baseline calibration we assume that defaulting on deposits causes deadweight resolution costs equal to a positive proportion of the assets repossessed by the DIA, while bail-in debt can be subject to haircuts without causing deadweight losses. Some recent experiences in Europe suggest that defaulting on bail-in debt may also carry deadweight losses (see Ip, 2016). We discuss such a case as an extension.

We calibrate the model and examine its implications for banks' socially optimal capital structure. As is common in the literature, the presence of insured deposits provides a strong need for loss absorbency since banks would otherwise choose to operate with no buffers and enjoy a large implicit bailout subsidy (Kareken and Wallace, 1978). We find that imposing total TLAC requirements similar in size to those currently proposed by the FSB properly trades off the preservation of liquidity services linked to deposits with the protection of the DIA against deadweight default costs.

Yet, our results imply an optimal mix of equity and bail-in debt quite different from that implied by forthcoming regulation. We find that, once TLAC is large enough so as to make default on insured deposits relatively unlikely, equity should only represent slightly above one quarter of optimal TLAC (or a little over 4% of total assets), with bail-in debt thus constituting the bulk of the loss-absorbing buffers. This is because, conditional on a large TLAC, private benefit taking is more tempting and socially costly at the margin than risk shifting. Intuitively, once the bailout subsidy associated with insured deposits is negligible, residual risk shifting does not involve large deadweight losses: it has mostly a redistributive impact (from bail-in debt holders to equity holders) which is compensated, in equilibrium, via the pricing of bail-in debt.<sup>4</sup>

Our paper fits in the growing literature that considers loss-absorbing liabilities different from equity in a banking context. Initial discussions centered on policy proposals suggesting the use of contingent convertibles (Flannery, 2005) or capital insurance (Kashyap, Rajan, and Stein, 2008) as means to “prepackage” the recapitalization of banks in trouble, reduce the reliance on government bail-outs, and prevent their negative ex ante incentive effects. Despite the early acknowledgement that bail-in debt could protect deposits or other senior debt against default losses (French et al, 2010), most of the existing academic research focuses on the going-concern version of contingent convertibles (‘cocos’), entertaining issues such as the choice of triggers (McDonald, 2013) and conversion rates (Pennacchi, Vermaelen, and Wolff, 2014), and their influence on the possibility of supporting multiple equilibria

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<sup>4</sup>In the absence of the buffer provided by bail-in debt, risk shifting would make deposits overly exposed to default, causing disproportionate deadweight losses.

(Sundaresan and Wang, 2015) and discouraging risk shifting (Pennacchi, 2010; Martynova and Perotti, 2014).

Papers in the existing literature typically study the effects of adding an ad hoc amount of contingent convertibles to some predetermined bank capital structure (typically in substitution for part of the uninsured debt). Our paper differs from the literature in that it looks at bail-in debt and addresses the capital structure and optimal regulation problems altogether, extracting conclusions for both the optimal size and the optimal composition of TLAC requirements. From a conceptual perspective, the most innovative aspect of our contribution is the consideration of a dual agency problem that makes the choice between bail-in debt and equity non-trivial. Most papers in the banking literature abstract from agency problems between inside and outside equity holders and put the emphasis on conflicts between equityholders as a whole and debtholders (or the DIA).<sup>5</sup>

The paper is structured as follows. Section 2 describes the model, the capital structure problem solved by the bank, and the expression for the net social surplus generated by the bank. Section 3 describes the calibration of the model. Section 4 examines its implications for the capital and TLAC requirements that maximize social surplus. In Section 5 we discuss the comparative statics of those requirements relative to relevant model parameters providing further understanding of the model logic and its guidance regarding how the optimal regulatory regime would depend on the characteristics of the environment. Section 6 discusses two extensions of the model. Finally, Section 7 concludes. The Appendix contains the mathematical derivation of the formulas used in the analysis.

## 2 The Model

We consider a bank tightly controlled by a group of risk-neutral insiders who, to sharpen the presentation, are assumed to be penniless and yet essential to manage the bank.<sup>6</sup> A bank is

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<sup>5</sup>By construction, the underlying models commonly feature an implicit or explicit dominance in terms of efficiency of equity over bail-in debt or cocos, unless equity issuance costs or corporate taxes provide an extra advantage to the latter.

<sup>6</sup>As further pointed out below (footnote 10), the analysis could be trivially extended to consider the case in which insiders are endowed with a limited amount of wealth that they can use to finance the bank. All

a one-period firm that invests in a fixed amount of assets with size normalized to one. The assets originated at a date  $t = 0$  yield a random return  $\tilde{R}$  at  $t = 1$  that depends on the realization of an idiosyncratic continuous bank-performance shock  $z$  at  $t = 1$ , the realization of a dichotomic risk state  $i = 0, 1$  at  $t = 1$ , as well as two unobservable choices made by the insiders at  $t = 0$ : (a) a risk shifting decision  $\varepsilon$  and (b) a private benefit taking decision  $\Delta$ .<sup>7</sup>

Specifically, bank asset returns conditional on reaching risk state  $i$  at  $t = 1$  are given by:

$$\tilde{R}_i = (1 - \Delta - h(\varepsilon))R_a \exp(\sigma_i z - \sigma_i^2/2), \quad (1)$$

where  $z \sim N(0, 1)$  and independent of the realization of  $i$ . So bank asset returns are, conditional on  $i$ , log-normally distributed with an expected value equal to  $(1 - \Delta - h(\varepsilon))R_a$ , and a variance that grows with  $\sigma_i$ , which switches depending on the risk state  $i$ .<sup>8</sup> We assume  $\sigma_0 < \sigma_1$  so that  $i = 0$  represents the ‘safe state’ and  $i = 1$  represents the ‘risky state.’  $R_a$  is the (exogenous) expected rate of return on bank assets when  $\Delta = h(\varepsilon) = 0$ .

The probability of ending up in the risky state  $i = 1$  equals  $\varepsilon$  and, hence, is directly controlled by insiders’ unobservable risk shifting decision  $\varepsilon \in [0, 1]$ . The function  $h(\varepsilon)$ , increasing and convex in  $\varepsilon$ , captures the negative impact of risk shifting on expected asset returns as commonly modelled in banking (e.g. Stiglitz and Weiss, 1981, and Allen and Gale, 2000, ch. 8).

Insiders’ unobservable private benefit taking diminishes expected asset returns by a fraction  $\Delta$  but directly provides a utility  $g(\Delta)$  to insiders (as in, e.g., Holmstrom and Tirole, 1997). Specifically, insiders maximize the expected value at  $t = 0$  of a utility function  $U$  which is linear in their consumption  $c$  at  $t = 1$  and in their private benefits  $g(\Delta)$ :

$$U = \beta c + g(\Delta), \quad (2)$$

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the results qualitatively go through if such wealth is small relative to the equity financing needed by the bank.

<sup>7</sup>Given that we focus the analysis on a single bank, the risk state  $i$  can be thought of as indistinctly driven by idiosyncratic or aggregate factors. In the latter case,  $\varepsilon$  could be thought of as the exposure of the individual bank to an aggregate risky state rather than directly the probability of such state.

<sup>8</sup>Having log-normal returns conditional on each risk state leads to having close form solutions for the valuation of bank securities similar to those in Black and Scholes (1973) and Merton (1977), while the variation of the risk state produces fat tails in the unconditional distribution of bank asset returns.

where  $\beta \in (0, 1)$  is the subjective discount factor and  $g(\cdot)$  is a strictly concave function with  $g'(0) = +\infty$  and  $g'(\bar{\Delta}) = 0$  at some  $\bar{\Delta}$  sufficiently lower than  $1 - h(1)$ , so that insiders' choice of  $\Delta$  is always contained in the interval  $(0, \bar{\Delta})$  and equilibrium solutions satisfy  $1 - \Delta - h(\varepsilon) > 0$  for all  $\varepsilon$ .

Bank assets are financed with endogenously determined amounts of common equity,  $e$ , uninsured bail-in debt,  $b$ , and insured deposits,  $d$ , raised from outside investors. Outside investors are also risk neutral and have the same subjective discount factor  $\beta$  as the insiders, but they are 'deep pockets' and, hence, able to supply funds elastically at an expected gross rate of return equal to  $1/\beta$ . Importantly, outside investors obtain a per-unit liquidity convenience yield  $\psi$  at  $t = 1$  from insured deposits, which makes them willing to accept a gross deposit rate  $R_d$  equal to  $1/\beta - \psi$ .

Insured deposits and bail-in debt promise endogenously determined gross returns of, respectively,  $R_d$  and  $R_b$  at  $t = 1$  per unit of funds invested at  $t = 0$ , while equity is a standard limited-liability claim on the residual cash flow of the bank at  $t = 1$ . Importantly, we assume that insiders' financial stake at the bank is the (endogenously determined) fraction  $\gamma$  of equity not sold to outside investors.

The bank is insolvent at  $t = 1$  if its asset returns  $\tilde{R}$  are insufficient to pay  $R_d d$  to insured depositors. In such a case, the deposit insurance agency (DIA) takes over the bank, pays insured deposits in full, and assumes residual losses equal to  $R_d d - (1 - \mu_d)\tilde{R}$ , where  $\mu_d$  is a deadweight asset-repossession cost. The DIA charges a premium  $p$  per unit of deposits at  $t = 0$ .

Importantly, the bail-in debt is junior to insured deposits and, when the bank defaults on it (that is,  $\tilde{R} < R_d d + R_b b$ ), bail-in debt holders receive a payoff  $(1 - \mu_b) \max\{\tilde{R} - R_d d, 0\}$ , where  $\mu_b \leq \mu_d$  is a deadweight asset-repossession cost.<sup>9</sup>

The bank is subject to two regulatory constraints: (a) a minimum capital requirement which imposes that at least a fraction  $\phi$  of its initial funding must be in the form of equity  $e$ ,

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<sup>9</sup>Having  $\mu_b \leq \mu_d$  could be justified as the result of especial resolution provisions that allow bail-in debt to be automatically converted into common equity or subject to hair-cuts in such a way that prevents the bank from being forced to liquidate illiquid assets so as to be able to pay its bail-in debtholders. The ratio  $(\mu_b - \mu_d)/\mu_d \in [0, 1]$  can be used as a measure of the efficiency of those provisions.

that is,  $e \geq \phi$ , and (b) a minimum total loss-absorbing capacity requirement (TLAC) which imposes that the bank must issue at least a fraction  $\chi \geq \phi$  of loss-bearing liabilities (equity or bail-in debt), that is,  $e + b \geq \chi$ . So, out of total loss-bearing liabilities, at least a fraction  $\phi$  must be common equity, while the remaining  $\chi - \phi$  can be indistinctly made up of bail-in debt or common equity.

Finally, the bank is also subject to corporate taxes: as under most common corporate tax codes, a tax rate  $\tau$  is levied on its positive earnings after interest (EAI) at  $t = 1$ .

## 2.1 The bank's capital structure problem

At date 0, prior to making their unobservable risk shifting and private benefit taking decisions,  $\varepsilon$  and  $\Delta$ , the bank insiders establish an overarching contract with the outside investors that fixes the capital structure of the bank as described by  $e$  and  $b$ , the fraction of bank equity retained by the insiders  $\gamma$ , the (gross) interest rates promised by bail-in debt  $R_b$  and insured deposits  $R_d$  and, implicitly, the insiders' subsequent private choices of  $\varepsilon$  and  $\Delta$ . The corresponding contract problem can be formally described as follows:

$$\max_{e,b,\gamma,R_b,R_d,\varepsilon,\Delta} \gamma E + g(\Delta) \quad (3)$$

subject to:

$$(1 - \gamma) E \geq e \quad [PC^E] \quad (4)$$

$$J - E \geq b \quad [PC^B] \quad (5)$$

$$\beta(R_d + \psi) \geq 1 \quad [PC^D] \quad (6)$$

$$(\varepsilon, \Delta) = \arg \max_{(\varepsilon', \Delta')} [\gamma E + g(\Delta')] \quad [IC] \quad (7)$$

$$e \geq \phi \quad [CR] \quad (8)$$

$$e + b \geq \chi \quad [TLAC] \quad (9)$$

where  $J$  and  $E$  are functions specified below.  $E$  represents the overall value at  $t = 0$  of the bank's common equity (that is, the stakes owned by both insiders and outsiders) and  $J$  is

the joint value of common equity and bail-in debt (so that the value of bail-in debt can be obtained as the difference  $J - E$ ).

Reflecting competition between the outside investors, the contract maximizes the insiders' expected utility,  $U = \gamma E + g(\Delta)$ , which equals the value of their equity stake,  $\gamma E$ , plus the private benefits obtained from the control of bank assets,  $g(\Delta)$ . The constraints of the maximization problem include the participation constraints of the investors who provide the bank with equity financing, (4), bail-in debt financing, (5), and insured deposit financing, (6).<sup>10</sup> The constraints also include (7) which is the incentive compatibility condition describing how insiders decide on  $\varepsilon$  and  $\Delta$  once the contract is in place.<sup>11</sup> Finally (8) and (9) reflect the existence of a minimum capital requirement  $\phi$  and a minimum TLAC requirement  $\chi$ .

The fact that, conditional on each risk state at  $t = 1$ , the gross asset returns of the bank, specified in (1), are log-normally distributed makes  $E$  and  $J$  easily expressible in terms of conventional Black-Scholes type formulas (see the Appendix for all derivations), with:

$$E = \beta \sum_{i=0,1} \varepsilon_i [(1 - \Delta - h(\varepsilon)) R_a F(s_i) - BF(s_i - \sigma_i)] - T, \quad (10)$$

where  $F(\cdot)$  is the cumulative distribution function (CDF) of a  $N(0, 1)$  random variable,

$$s_i = \frac{1}{\sigma_i} [\ln(1 - \Delta - h(\varepsilon)) + \ln R_a - \ln B + \sigma_i^2/2], \quad (11)$$

$B = R_d d + R_b b$  is the overall contractual repayment obligation on deposits and bail-in debt, and  $T$  is the expected present value of corporate taxes. The amount of deposit funding  $d$  needed to pay for the initial asset investment of one and the deposit insurance premium  $pd$  under any given choices of  $e$  and  $b$  can be found as the solution to  $e + b + d = 1 + pd$ , that is,

$$d = \frac{1 - e - b}{1 - p}. \quad (12)$$

As shown in the Appendix, the threshold  $s_i$  is such that  $F(s_i - \sigma_i)$  is the probability with which bail-in debt is paid back in full in state  $i$ .

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<sup>10</sup>Extending the analysis to the case in which insiders can contribute some wealth  $w < e$  as equity financing to the bank would simply require replacing (4) with  $(1 - \gamma)E \geq e - w$ .

<sup>11</sup>If the solutions in  $(\varepsilon, \Delta)$  are interior, (7) can be replaced, as usual, by the first order conditions associated with each of the choice variables.

Conveniently, the joint value of equity and bail-in debt can be expressed as follows:

$$J = \beta \sum_{i=0,1} \varepsilon_i \left\{ (1-\Delta-h(\varepsilon)) R_a F(w_i) - R_d d F(w_i - \sigma_i) - \mu_b (1-\Delta-h(\varepsilon)) R_a (F(w_i) - F(s_i)) \right\} - T, \quad (13)$$

where

$$w_i = \frac{1}{\sigma_i} \left[ \ln(1 - \Delta - h(\varepsilon)) + \ln R_a - \ln R_d - \ln d + \sigma_i^2/2 \right], \quad (14)$$

and  $F(w_i - \sigma_i)$  is the probability with which the bank is able to pay back its insured deposits in full in state  $i$ .<sup>12</sup> The term multiplied by  $\mu_b$  accounts for the deadweight losses incurred when the bail-in debt cannot be paid in full but the bank does not default on its deposits. The value of the bail-in debt at  $t = 0$  is therefore equal to  $J - E$ .

Finally, the expected present value of corporate taxes can be written as

$$T = \beta \tau \sum_{i=0,1} \varepsilon_i \left[ (1 - \Delta - h(\varepsilon)) R_a F(t_i) - (B + e) F(t_i - \sigma_i) \right], \quad (15)$$

where

$$t_i = \frac{1}{\sigma_i} \left[ \ln(1 - \Delta - h(\varepsilon)) + \ln R_a - \ln(B + e) + \sigma_i^2/2 \right], \quad (16)$$

and  $F(t_i - \sigma_i)$  is the probability with which the bank obtains positive EAI (and hence pays positive taxes) in state  $i$ .<sup>13</sup> As confirmed by the derivations in the Appendix, the way  $B + e$  enters (15) and (16) takes into account that the interest paid on deposits and bail-in debt is tax deductible while the (net) payouts to equity are not.

## 2.2 Deposit insurance costs and the social value of the bank

The presence of the safety net for depositors implies the existence a liability, the so-called Merton Put identified by Merton (1977), for the DIA and, if deposit insurance premia are

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<sup>12</sup>The presence of bail-in debt,  $R_b b$ , makes  $B > R_d d$  and hence  $s_i < w_i$ , implying the existence of an interval of return realizations for which the bank does not default on deposits but cannot pay bail-in debt in full.

<sup>13</sup>Clearly, with  $e > 0$ , we have  $t_i < s_i$ , implying the existence of an interval of asset return realizations for which the bank does not default on deposits but still has negative EAI and, hence, pays no taxes.

insufficient to cover it, for tax payers. Net of the deposit insurance premium charged on the bank at  $t = 0$ , the present value of the deposit insurance liability is:

$$DI = \beta \sum_{i=0,1} \varepsilon_i [R_d d (1 - F(w_i - \sigma_i)) - (1 - \mu_d) (1 - \Delta - h(\varepsilon)) R_a (1 - F(w_i))] - pd. \quad (17)$$

Finally, the net social surplus generated by the bank can be computed as:

$$W = U + T - DI, \quad (18)$$

since stakeholders other than the bank's insiders (with surplus measured by  $U$ ) and tax payers (with surplus measured by  $T - DI$ ) simply break-even when their participation constraints in (4)-(6) are binding, as they happen to be in equilibrium.

### 3 Calibration

Our model is rich in its structure and contains a number of realistic features (e.g. DI premia, corporate taxes, agency costs) which are important determinants of the bank's capital structure. These model features are needed to deliver empirically plausible implications for the setting of bank capital and TLAC requirements. Consequently our calibration strives to match important data moments, thus ensuring that the model is well empirically grounded prior to its use for policy analysis. Table 1 displays the baseline calibration. All the parameters have already been introduced in the model section except those describing functions  $h(\cdot)$  and  $g(\cdot)$ , which will be specified below.

The model is calibrated by assuming that one period is one year. The discount rate  $\beta$  equals 0.9838, delivering a real annual risk free interest rate of 1.65% which is the average ex-post real interest rate on 3-month US Treasury bills over the 1985-2006 period. The ex post real interest rate is computed by subtracting CPI inflation from the nominal yield. The calibration period is chosen to represent 'normal times,' avoiding the Great Inflation and subsequent Volcker disinflation years prior to 1985 and also the 2007-2010 financial crisis and its aftermath.

Table 1: Baseline parameter values

Investors' discount factor	$\beta$	0.983
Deposits' liquidity convenience yield	$\psi$	0.0071
Gross return on bank assets (if $\Delta=\varepsilon=0$ )	$R_a$	1.03
Deadweight loss from default on deposits	$\mu_d$	0.20
Deadweight loss from default on bail-in debt	$\mu_b$	0.00
Corporate tax rate	$\tau$	0.25
Deposit insurance premium	$p$	0.0006
Capital requirement (CET1)	$\phi$	0.04
TLAC requirement (CET1 + other TLAC)	$\chi$	0.08
Cost of risk shifting parameter	$h_1$	0.6397
Risk shifting elasticity parameter	$h_2$	2.2103
Private benefit level parameter	$g_1$	0.0001
Private benefit elasticity parameter	$g_2$	0.1669
Private benefit extra curvature parameter	$g_3$	0.025
Asset risk in the safe state	$\sigma_0$	0.0319
Asset risk in the risky state	$\sigma_1$	0.1145

The liquidity convenience yield  $\psi$  is a key determinant of the private and social incentives to finance the bank with insured deposits. We set  $\psi = 0.0071$  by matching the difference between the average return on 3-month Treasury bills and the average return to bank deposits after adjusting for the bank's costs of deposit-taking activities.<sup>14</sup> We obtain Treasury yields data from FRED and use FDIC data to estimate the return on bank deposits as Total Interest Expense over Total Debt. To estimate the bank's non-interest cost of deposit-taking activities, we rely on FDIC data on banks' Total Non-interest Expense. However, such item does not distinguish between costs related to taking deposits and costs related to making loans. We therefore establish some plausible bounds to the size of the former and take the middle point of this range. At one extreme, if all of the non-interest expenses were incurred providing loans, the liquidity premium would be around 140bps. At the other extreme, if 2/3 of the costs were attributable to deposit-taking, the premium would be zero. We take

<sup>14</sup>In other words, while the difference between Treasury yields and deposit rates give us a 'gross  $\psi$ ' that reflects depositors' willingness to pay for the underlying liquidity services, we feed the formulas for bank value and social surplus with the 'net  $\psi$ ' which comes from subtracting from 'gross  $\psi$ ' some inputted cost of providing those liquidity services.

the mid-point of this range which implies attributing 1/3 of non-interest expenses to the provision of deposit services. This gives a liquidity premium of 70.6bps.

We use the same FDIC data to calibrate the average loan return after adjusting for banks' non-interest cost of loan-making. We compute the average nominal loan interest rate as Total Interest Income over Total Assets and deflate it by the CPI inflation rate. Again, we use data for 1985-2006. The calibration implies that the average real loan interest rate net of loan-making costs is 3.16% per annum, which explains the calibrated value of  $R_a$ .

The bankruptcy cost parameter for insured deposits  $\mu_d$  is set equal to 0.2 in line with the findings of Bennett and Unal (2014) based on FDIC resolutions in the 1986-2007 period. In the baseline calibration, the deadweight loss implied by bail-in debt haircuts,  $\mu_b$ , is set to zero. This polar choice is based on the inexistence of evidence allowing us to calibrate it from the the data and implies assuming that the current legal bank resolution framework guarantees a frictionless bail-in process. We explore different values for this parameter in extensions to the baseline analysis.

We set the capital requirement  $\phi$  equal to 0.04 in line with the requirement of Tier 1 capital under Basel II (assuming a reference risk weight of 100% on bank assets). As for the TLAC requirement  $\chi$ , we set it equal to 0.08 in line with the Tier 1 plus Tier 2 capital requirement in Basel II, since the type of liabilities other than common equity that were allowed to compute as Tier 2 capital (preferred stock and subordinated debt) had loss-absorbing capacity similar to that currently foreseen for bail-in debt.

We fix the DI premium to 6 bps in line with the DI premium paid by US banks in Risk Category I (CAMELS ratings 1 and 2) since 2011.<sup>15</sup> We also assume that the DI premium is not risk sensitive even though in reality it depends on each bank's CAMELS rating. Our reason for assuming a non-risk-sensitive premium comes from the evidence in Bassett, Lee and Spiller (2012) who show that, in 2006, around 92% of US banks were in the highest two CAMELS ratings (versus 60% in 2009), which we read as meaning that making DI premia

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<sup>15</sup>Since 2011, the FDIC requires DI premia in the range from 2.5 to 9bps for banks with CAMELS ratings 1 and 2. Our choice of 6bps roughly corresponds to the middle of this range. For more information, see <https://www.fdic.gov/deposit/insurance/assessments/proposed.html>

truly risk-sensitive *ex ante* is very difficult. Under our calibration, the bank’s model-implied Z-score is close to 3.3 which is consistent with a high CAMELS rating and a DI premium of 6bps.<sup>16</sup> The bank corporate tax rate is set equal to 25% in line with the average tax rate for financials reported in the data set maintained by Aswath Damodaran.<sup>17</sup>

Regarding the private benefits function, we specify it as follows:

$$g(\Delta) = \frac{g_1}{g_2} \Delta^{g_2} - g_3 \Delta \quad (19)$$

with  $g_1 \geq 0$ ,  $0 < g_2 < 1$  and  $g_3 \geq g_1$ . This specification makes  $g(\Delta)$  concave for  $0 < \Delta < 1$ , with  $g'(0) = \infty$  and  $g'(1) \leq 0$ , guaranteeing equilibrium choices of  $\Delta$  lower than 1. Parameter  $g_1$  controls the size of the private benefits while  $g_2$  controls the elasticity of  $\Delta$  with respect to insiders’ equity share  $\gamma$ . Parameter  $g_3$  is introduced for purely technical reasons: setting it sufficiently above  $g_1$  helps to obtain interior solutions with  $1 - \Delta - h(\varepsilon) > 0$  without significantly affecting the equilibrium contract.<sup>18</sup> Similarly, the sacrifice in expected returns associated with risk shifting is assumed to be given by

$$h(\varepsilon) = \frac{h_1}{h_2} \varepsilon^{h_2}, \quad (20)$$

with  $h_1 > 0$  and  $h_2 > 1$ .

We have no direct evidence on the private benefit parameters (essentially,  $g_1$  and  $g_2$ ) and the cost of risk shifting parameters ( $h_1$  and  $h_2$ ). Therefore we pick those parameters as well as banks’ asset return volatilities in the safe and risky states ( $\sigma_0$  and  $\sigma_1$ ) in order to match six data moments.

Target 1. For calibration purposes, we will interpret the ‘risky state’ in the model as capturing aggregate conditions in which bank failure is abnormally high (that is, financial crises) and the ‘safe state’ as representing normal times. We therefore target the probability of the risky state ( $\varepsilon$ ) that matches the observed frequency of crises. It is always difficult to

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<sup>16</sup>See footnote 20 for a definition of the model-implied Z-score.

<sup>17</sup>This data can be downloaded from <http://www.stern.nyu.edu/~adamodar/pc/datasets/taxrate.xls>

<sup>18</sup>It can be show that  $g_3$  has a small effect on the shape of the function  $g(\Delta)$  at low values of  $\Delta$  (which are the economically relevant ones) but a significant effect at large values.

calibrate the probability of rare events such as financial crises. Since 1900, the US has experienced four banking crises<sup>19</sup> implying a crisis probability of around 3% per annum. However, the period since 1900 includes the Second World and the Bretton Woods period (1939-1972) when financial repression ensured that the financial system was unusually stable. Excluding this period leaves 4 crises in 83 years or approximately a 5% annual crisis probability.

Targets 2 and 3. We match the evidence on bank defaults in ‘normal times’ ( $P_0 = 1 - F(w_0 - \sigma_0)$ ), and in crises or ‘risky times’ ( $P_1 = 1 - F(w_1 - \sigma_1)$ ) from Laeven and Valencia (2010). They analyze bank failures during the last financial crisis and find a wide range of estimates depending on the precise definition of bank failure. For example, in the US actual bankruptcies occurred in banks holding less than 6% of total bank deposits. However, if one associates bank failure with receiving some form of government assistance, the fraction of total deposits at failed banks reaches values above 20%. We therefore target a bank default rate in risky times equal to 20%. In normal times we target a very low default rate equal to 0.05% reflecting the fact that major banks usually do not fail outside crisis periods.

Target 4. We match the share of bank equity owned by insiders ( $\gamma$ ). It is not straightforward to compute the data counterpart to this variable. Direct management ownership (including ownership by close family) provides perhaps the narrowest definition. Based on US banks for the 1990-95 period, Berger and Udell (2006) report a number of 9.3% of total equity. However, insiders can be more broadly defined to also include those shareholders who, without being managers, can effectively hold management to account, e.g. institutional shareholders and other large shareholders. On this broad definition, Berger and Udell (2006) report a share of inside equity of 17.2% of total equity for US banks. This is the inside equity share we target.

Target 5. To parameterize the curvature of the  $h(\varepsilon)$  function, we use the evidence in Laeven and Levine (2010) who estimate that the derivative of banks’ Z-score with respect to capital ratio changes is equal to 0.2. The standard deviation of the estimate is 0.09. We

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<sup>19</sup>Those were the 1907 crisis, the Great Depression, the Savings and Loan Crisis and the recent Global Financial Crisis.

compute numerical derivatives of the bank’s Z-score around the baseline parameter values and aim to match this to the estimates of Laeven and Levine (2010).<sup>20</sup>

Target 6. To parameterize the curvature of the  $g(\Delta)$  function, we target the share of Tier 1 Capital in Total Capital. For the 1986-2006 period, the average value of that share for US banks is roughly 75%. However, most banks hold voluntary capital buffers (typically in the form of Tier 1 Capital) on top of the regulatory minima to avoid the risk of suddenly breaching the minima. Since our model does not produce voluntary buffers, we control for them by subtracting the average excess of the Total Capital ratio over the regulatory 8% from both the Tier 1 Capital ratio and the Total Capital ratio. After this adjustment, the average share of Tier 1 Capital in Total Capital is 56.3%. This is the sixth data moment we target in the calibration.<sup>21</sup>

The calibration procedure seeks the parameter vector  $[g_1, g_2, h_1, h_2, \sigma_1, \sigma_2]$  which minimizes the sum of squared percentage deviations of the model implied moments from the above six targets. The procedure is performed with the Nelder-Meade algorithm as implemented in the Matlab function `fminsearch.m`.

## 4 Quantitative Results

Table 2 below summarizes the results of the bank’s capital structure problem under the baseline parameters values. The probability of bank default in the model is small in normal times (0.07%) and substantial in risky times (20.1%). Risky times occur with a probability of 5%.

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<sup>20</sup>The Z-score is conventionally defined as  $(\text{ROA} + \text{Equity Ratio}) / (\text{Standard Deviation of ROA})$ , which in model terms we can measure as

$$\text{Z-score} = \sum_{i=0,1} \varepsilon_i \frac{[(1 - \Delta - h(\varepsilon)) R_a - 1] + (e + b)}{\sigma_i}$$

where  $i$  indexes the risk state and we interpret Equity broadly as the sum of all loss absorbing liabilities,  $e + b$ .

<sup>21</sup>After this adjustment, the capital requirement is very close to binding and, indeed, it is binding at the calibrated parameter values as the model would find it easier to match our six targets with a capital ratio lower than the minimum. Eventually we found that Targets 1-5 provided sufficient information to calibrate parameter  $g_2$  even in the region where the capital requirement becomes binding.

Under the baseline calibration, the equity retained by bank insiders ( $\gamma$ ) represents just under one quarter of the total. This is higher than the 17.2% we target but is still in line with the international evidence. Caprio, Laeven and Levine (2007) use a sample of 244 banks from 44 countries and report average cash flow rights for banks' ultimate controlling owners of 26%. Our implied value is consistent with their findings.

The unconditional expected value of the deposit insurance subsidy,  $DI$ , is around 0.19% of total bank assets which implies that deposit insurance is somewhat underpriced from a long run perspective.<sup>22</sup> DI costs realize mostly in risky times, where they represent about 3.4% of bank assets. This is broadly consistent with the deposit insurance costs during crises documented by Laeven and Valencia (2010), whose median estimate is 2.1% of bank assets for advanced economies and 12.7% of bank assets for all economies. Finally, it is worth noting that most of the losses suffered by the DIA are accounted for by the deadweight losses ( $DWL$ ) associated with the presence of the asset repossession cost  $\mu_d > 0$ . Under our parameterization,  $DWL$  represents on average about 18bps of total bank assets.

Table 2: Baseline results

Common equity as % of assets	$e$	4.00
Bail-in debt as % of assets	$b$	4.00
Insider equity as % of total equity	$\gamma$	24.2
Asset returns lost due to private benefit taking (%)	$\Delta$	0.15
Asset returns lost due to risk shifting (%)	$h(\varepsilon)$	0.04
Probability of the risky state realizing (%)	$\varepsilon$	5.02
Bank Z-score (as defined in footnote 20)	Z-score	3.31
Derivative of Z-score with respect to equity	$\partial(\text{Z-score})/\partial e$	0.32
Probability of defaulting on deposits in the safe state (%)	$P_0$	0.07
Probability of defaulting on deposits in the risky state (%)	$P_1$	20.1
Deposit insurance subsidy as % of assets	$DI$	0.19
Deadweight default losses as % of assets	$DWL$	0.18
Expected NPV of taxes as % of assets	$T$	0.64
Private value of the bank as % of assets	$U$	1.49
Social value of the bank as % of assets	$W$	1.94

The baseline calibration implies that the reduction in asset returns due to private benefit

<sup>22</sup>Of course, in normal times, when bank risk is very low, deposit insurance would appear overpriced.

taking ( $\Delta$ ) and risk shifting ( $h(\varepsilon)$ ) amount around 0.15% and 0.04% of total bank assets, respectively. Insiders' overall payoff  $U$  (including private benefits) amounts to around 1.5% of bank assets. Finally, the net social surplus generated by the bank,  $W = U - DI$ , equals 1.94% of bank assets. This is higher than the private surplus reflecting that the average corporate taxes paid by banks substantially exceed the average net deposit insurance subsidy.

## 4.1 Examining agency costs

Our model is rich and in order to disentangle the trade-offs associated with each agency problem we begin by first analyzing special cases in which either none or only one of the agency problems is present. After understanding the impact of each agency problem in isolation, we study the socially optimal capital and TLAC requirements when both of them are present.

### 4.1.1 The model without agency costs

We start with the model in which both  $\Delta$  and  $\varepsilon$  are fully contractible. In this case, we solve the problem stated in (3)-(9) without imposing (7). In Table 3 below we show how the solution to the bank's capital structure problem changes depending on the level of the capital and TLAC requirements,  $\phi$  and  $\chi$ . As a reference, the first row of the table reports the results under the baseline regime with  $\phi=0.04$  and  $\chi=0.08$ . In the last row of the table we present the capital and bail-in debt requirements that maximize social welfare.

Table 3: Comparative statics with no agency costs (%)

	$e$	$b$	$\gamma$	$\Delta$	$\varepsilon$	$P_0$	$P_1$	$DI$	$T$	$U$	$W$
Baseline regime*	4.00	4.00	26.0	0.03	2.12	0.06	19.7	0.05	0.65	1.55	2.16
$\phi=\chi=0.08$	8.00	0.00	13.8	0.03	1.44	0.06	19.7	0.03	0.67	1.53	2.18
$\phi=0,\chi=0.08$	0.00	8.00	100	0.03	3.43	0.06	19.7	0.11	0.51	1.70	2.10
Optimal regime**	9.78	0.00	12.3	0.03	0.02	0.04	15.3	-0.05	0.67	1.51	2.23

\* In the baseline regime  $(\phi, \chi)=(0.04, 0.08)$ . \*\* In the optimal regime  $(\phi, \chi)=(0.098, 0)$ .

The model without agency costs works very differently from the full model when subject to the baseline regulatory regime. Since private benefit taking is fully contractible,  $\Delta$  is

extremely low compared to the outcome under the baseline calibration with the full model. Equally the bank's risk choice  $\varepsilon$  is fully contractible resulting in a low value of 2.1% per annum. Nevertheless, it is worth noting that  $\varepsilon$  remains above its asset return maximizing value of 0. This is because the bank still has an incentive to take excessive risk in order to enjoy the DI subsidy. Since the banking contract is designed to maximize insiders' value, it still delivers more risk-taking than is socially optimal. This discrepancy provides a rationale for regulating the bank's capital structure decisions also in this case.<sup>23</sup>

The next row in the table examines the consequences of forcing the bank to use only common equity ( $\phi=\chi=0.08$ ). More 'skin-in-the-game' for shareholders leads to a smaller exposure to the risky state ( $\varepsilon$  falls to 1.4% per annum) but this is balanced out by a slightly greater tax bill. Due to the higher tax liability, the value of the contract to insiders ( $U$ ) falls while, due to the lower risk-taking, the social value ( $W$ ) rises compared to the baseline.

In contrast, removing the requirement to issue any common equity ( $\phi=0,\chi=0.08$ ) generates an even higher private and an even lower social value. By using bail-in debt as the only loss absorbing liability, the bank economizes even more on corporate taxes while diminishing the incentive to refrain from risk shifting, which leads to an increase in the expected DI subsidy.

The final row shows the optimal capital requirement ( $\phi=0.098$ ) in this version of the model. The overall size of the bank's buffers is not very large but it is entirely composed of common equity. This disciplines the risk taking of the bank's insiders:  $\varepsilon$  falls to 0.02% leading to the DI subsidy falling almost to zero.

In the end, our model without agency costs features some well-known 'trade-offs'. The optimal total buffer size trades off liquidity convenience yield versus deadweight default costs. Further increases in the size of the bank's buffers could drive  $\varepsilon$  closer to its asset return maximizing value of zero but the cost in terms of diminished supply of insured deposits (which have a liquidity convenience yield) is too large.

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<sup>23</sup>Of course, in the case when  $\varepsilon$  and  $\Delta$  are observable, the regulator could directly regulate those. In this case, it could set  $\varepsilon = 0$  and the first best value of  $\Delta$  and the composition of the total loss absorbing buffer would be irrelevant for welfare. For didactic reasons, we restrict attention to regulations exclusively involving the requirements  $\phi$  and  $\chi$  as in the full model where  $\varepsilon$  and  $\Delta$  are unobservable.

The buffer composition is privately resolved in favour of debt due to its tax advantages but socially, common equity is preferred. This is entirely due to the distortionary impact of deposit insurance. From a social point of view the taxes redistribute between bank insiders and taxpayers and their level per se does not make one arrangement preferred to another. Hence common equity is preferred to bail-in debt because it is better at diminishing the DI subsidy that creates an incentive for bank shareholders to choose an excessive value of  $\varepsilon$ . Achieving the same reduction of risk shifting with bail-in debt only would have required a larger overall buffer and hence a larger cost in terms of foregone liquidity benefits of insured deposits. This is why relying in common equity is socially preferred.

#### 4.1.2 Risk-shifting only

In the second special case, we shut down the moral hazard problem associated with private benefit taking: we assume that the choice of  $\Delta$  is fully contractible, while the choice of asset riskiness  $\varepsilon$  remains unobservable. In this case, we solve the problem stated in (3)-(9) with a version of (7) in which insiders' only private decision is  $\varepsilon$ .

Table 4: Comparative statics with uncontractible risk-shifting only (%)

	$e$	$b$	$\gamma$	$\Delta$	$\varepsilon$	$P_0$	$P_1$	$DI$	$T$	$U$	$W$
Baseline regime*	4.00	8.00	25.8	0.03	4.93	0.06	19.8	0.18	0.67	1.54	2.03
$\phi=\chi=0.08$	8.00	0.00	14.7	0.03	1.44	0.06	19.7	0.03	0.67	1.53	2.18
$\phi=0,\chi=0.08$	1.23	6.77	53.3	0.03	9.18	0.07	20.0	0.37	0.59	1.55	1.77
Optimal regime**	9.78	0.00	12.3	0.03	0.02	0.04	15.3	-0.05	0.67	1.51	2.23

\* In the baseline regime  $(\phi, \chi)=(0.04, 0.08)$ . \*\* In the optimal regime  $(\phi, \chi)=(0.098, 0)$ .

Under the baseline policy regime, the model with only risk shifting distortions works similarly to the full model. The capital requirement is binding despite the fact that risk-shifting is the only agency friction facing the bank (the mitigation of which calls for higher equity). This is because higher leverage and higher risk allows the bank to pay lower taxes and enjoy a higher DI subsidy.

The next row examines the consequences of forcing the bank to use only common equity ( $\phi=\chi=0.08$ ). This leads the bank to reduce dramatically its risk taking ( $\varepsilon$  falls) with two

consequences. First, the DI subsidy declines considerably and hence the private value of the bank falls albeit by a small margin since the lower DI subsidy is counterbalanced by lower return losses from risk shifting. This makes clear that an equity heavy capital structure would be the optimal choice for such a bank in the absence of safety net distortions. The second consequence of forcing the bank to fund itself more with equity is a big reduction in dead-weight default losses, resulting in a significant increase in social welfare.

The third row demonstrates the consequences of leaving the buffer composition entirely to the bank's discretion ( $\phi=0, \chi=0.08$ ). It reveals that the bank will voluntarily hold some equity but it will be small due to the safety net distortions discussed above but still more than the analogous case in Table 3. Here, since  $\varepsilon$  is private information, holding some equity is a way for insiders to commit not to take too much risk ex post. Nevertheless, the contract is only optimal from a private point of view as can be seen from the increase in the private value to the insiders. Risk-shifting is still very large ( $\varepsilon$  is higher than 9%) and this leads to very high default losses and very low social welfare. This result underscores the fact that, even though the private costs of risk-shifting are relatively small (recall discussion of the baseline results in Table 2), they generate large social costs of bank failure which are mostly paid for by the DI agency.

The final row shows the optimal capital requirement ( $\phi=0.098$ ) in this version of the model. Similarly to Table 4, a high capital ratio discourages risk taking and drives the value of  $\varepsilon$  to levels close to zero. The contract is able to manage the single agency friction very well and the social value ( $W$ ) is almost at the same level as in the case when  $\varepsilon$  is contractible.

### 4.1.3 Private benefit taking only

Another special case of our model occurs when the private benefit taking decision  $\Delta$  is unobservable but the  $\varepsilon$  choice is fully contractible. In this case, we solve the problem stated in (3)-(9) with a version of (7) in which insiders' only private decision is  $\Delta$ .

Table 5: Comparative statics with uncontractible private benefit taking only (%)

	$e$	$b$	$\gamma$	$\Delta$	$\varepsilon$	$P_0$	$P_1$	$DI$	$T$	$U$	$W$
Baseline regime*	4.00	4.00	24.6	0.15	2.07	0.07	20.0	0.04	0.63	1.50	2.08
$\phi=\chi=0.08$	8.00	0.00	12.9	0.28	1.44	0.08	20.3	0.03	0.63	1.39	1.99
$\phi=0,\chi=0.08$	0.00	8.00	100	0.05	3.38	0.06	19.8	0.11	0.51	1.69	2.09
Optimal regime**	0.16	13.4	90.2	0.06	1.12	0.00	8.05	-0.03	0.51	1.64	2.18

\* In the baseline regime  $(\phi, \chi)=(0.04, 0.08)$ . \*\* In the optimal regime  $(\phi, \chi)=(0.002, 0.136)$ .

The first row of Table 5 presents the baseline regime of this private-benefits-only version of the model. This yields outcomes that are relatively similar to those of the full baseline model (Table 2) apart from the decline of  $\varepsilon$  to 2.1%. Again  $\varepsilon$  does not fall to the surplus maximizing value of zero due to the safety net subsidy.

If only subject to a capital requirement ( $\phi=\chi=0.08$ ), the bank is pushed to place equity among outsiders,  $\gamma$  declines and, as a result, private benefit taking increases substantially ( $\Delta=0.28$ ) relative to the baseline regime. Intuitively, having less skin in the game leads insiders to extract a higher level of private benefits. This has a negative effect on efficiency, leading the private and social values of the bank to become lower than in the baseline regime. As losses from private benefit taking eat into asset returns, the probability of bank default increases in both states. The conclusion is that, if private benefit taking is the key agency distortion, requiring banks to be funded with a large proportion of outside equity is a poor way to ensure their resilience. With less skin in the game, bank insiders run the bank further away from the socially optimum.

Row 4 explores the regime that only relies on the TLAC requirement ( $\chi=0.08$  with  $\phi=0$ ). We observe that, if banks can decide how to satisfy such requirement, they choose bail-in debt rather than outside equity. In these two rows,  $\Delta$  remains very low (less than 25% of its value under  $\phi=\chi=0.08$ ). The private and social values of the bank improve relative to those in the first two rows. When private benefit taking is important, bail-in debt is strongly privately and socially preferred to outside equity. This is an instance of the good incentive properties of outside debt financing shown by Innes (1990). However, in this case the overall buffer is not large enough and the residual deposit insurance distortion encourages the bank

to increase  $\varepsilon$  to 3%.

In the optimal regulatory regime for this special case, the TLAC requirement should be set equal to around 13.6% of assets and accompanied with a very small capital requirement of 0.2%. Essentially, the optimal policy reduces the probability of defaulting on deposits (and, hence, the marginal DI subsidy), thus reducing insiders' incentive to take excessive risk. There are of course limits to how much  $\varepsilon$  can be reduced since larger buffers reduce the liquidity benefits from having insured deposits. So the optimal policy tolerates a 1.1% probability of the risky state realizing because further reductions would not compensate the implied losses of liquidity services associated with deposits.

The residual role for the capital requirement in this case is explained by its higher effectiveness (at the margin) to control the distortions that the DI subsidy introduces in insiders' decision on  $\varepsilon$ .<sup>24</sup> However, imposing  $\phi=0$  and re-optimizing on  $\chi$  would only cause a small decline in welfare, confirming that the role played by outside equity in this especial case is very marginal.

## 4.2 Optimal capital and TLAC requirements in the full model

We started by exploring the two agency problems in the model (risk shifting and private benefit taking) in versions of our framework with only one of them. From these exercises we learned that bail-in debt provides better incentives than equity against private benefit taking while equity is superior to bail-in debt in dealing with risk shifting. In this section we examine the implications of the full model for optimal capital and TLAC requirements.

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<sup>24</sup>Of course, if  $\varepsilon$  were directly regulated (which in this case is theoretically feasible), it could be set equal to its socially optimal value of zero and there would be no residual role for  $\phi > 0$ . The protection against the deadweight losses from bank default would entirely rely on bail-in debt.

Table 6: Comparative statics of the full model (%)

	$e$	$b$	$\gamma$	$\Delta$	$\varepsilon$	$P_0$	$P_1$	$DI$	$T$	$U$	$W$
Baseline regime*	4.00	4.00	24.4	0.15	5.02	0.07	20.1	0.19	0.64	1.49	1.94
$\phi=\chi=0.08$	8.00	0.00	12.9	0.28	1.56	0.08	20.3	0.03	0.63	1.39	1.99
$\phi=0.0, \chi=0.08$	0.97	7.03	58.4	0.08	10.0	0.07	20.2	0.42	0.56	1.53	1.68
Optimal regime**	4.33	12.2	21.6	0.17	4.76	0.00	4.55	-0.01	0.62	1.39	2.02

\* In the baseline regime  $(\phi, \chi)=(0.04, 0.08)$ . \*\* In the optimal regime  $(\phi, \chi)=(0.043, 0.166)$ .

We begin in Table 6 with an analysis of different capital and TLAC requirements. Several things become immediately clear. First, setting a very high capital requirement is not the best solution. If the baseline level of TLAC is forced to consist exclusively of equity ( $\phi=\chi=0.08$ ), the social value of the bank ( $W$ ) mainly because of the sizeable reduction in risk shifting but that comes at the cost of an also sizeable increase in private benefit taking. The latter happens because the raising the additional equity externally dilutes insiders' equity stake to about half of its baseline level.

Second, going to the other extreme and removing the capital requirement ( $\phi=0$ ) while requiring the same TLAC as in the baseline regime ( $\chi=0.08$ ) is even worse. The bank reacts by drastically reducing its equity financing as this allows it to better deal with private benefit taking and to save on taxes. However, this debt-heavy structure involves a high level of risk shifting, with most of its costs paid for by the deposit insurance system. Consequently, the private value of the bank increases a little bit but its social value falls quite sharply.

Looking the last row of the table, we can see that the optimal regulatory regime involves differentiated capital and TLAC requirements, inducing the mix of a significant but relatively low portion of equity financing (4.3% of bank assets) with a large portion of bail-in debt financing (over 12% of bank assets) giving a large overall TLAC buffer (16.6% of bank assets) that is a little below the FSB's proposals. Under the optimal regime, risk shifting remains significant ( $\varepsilon = 0.048$ ) due to the low equity ratio. However, while the risk of bank failure in the risky state remains non-negligible (4.6%), it is substantially reduced relative to the baseline. Trying to further reduce the level of risk shifting  $\varepsilon$  by means of imposing a larger  $\phi$  would imply further dilution of insiders' ownership and hence losses due to the increase

in private benefit taking  $\Delta$  (as in the second row of Table 6). Equally, trying to further reduce the probability of defaulting on deposits via higher overall buffers would lead to costs in terms of lower liquidity services.

The optimality of combining a capital requirement with a larger TLAC requirement (so as to eventually induce the combined use of equity and bail-in debt) reflects the interaction of two important trade-offs. First, the trade-off between the two agency problems (private benefit taking and risk shifting), which drives the optimal composition of the buffers against bank default. Secondly, the trade-off between the deadweight costs of bank default and the liquidity benefits of insured deposits, which drives the optimal overall size of those buffers.

Relative to the baseline regulatory regime, our calibration implies significantly larger overall buffers (16.6% vs. 8%) and prescribes that most of the increase should consist of bail-in debt. This surprising result reflects the fact that, once the likelihood of defaulting on insured deposits is sufficiently low (thanks to the large buffers), the risk shifting problem (against which equity is the most effective tool) becomes a lesser evil than private benefit taking (against which bail-in debt works better). Bail-in debt holders get compensated from their non-negligible risk of experiencing haircuts in the risky state through the endogenous high yields paid by their debt.

The social value of the bank in the socially optimal regime of Table 6 is considerably lower than its counterparts in either of the two single-distortion cases (Tables 4 and 5). The combination of the two agency problems produces trade-offs between addressing each of them, keeping the corresponding second best allocation further distant from the first best.

#### **4.2.1 Importance of the two requirements**

The optimal regulatory regime involves a minimum capital requirement as well as a minimum TLAC requirement, instead of just one of the two. In Table 7, we study the implications of removing the minimum capital requirement (that is, making  $\phi=0$  while keeping  $\chi=0.166$ ) as well as the implications of ignoring bail-in debt (making  $\phi=\chi$ ) and imposing the social value maximizing capital requirement ( $\phi=0.085$ ).

Table 7: The optimal regime and the ‘TLAC only’ and ‘capital only’ regimes (%)

	$e$	$b$	$\gamma$	$\Delta$	$\varepsilon$	$P_0$	$P_1$	$DI$	$T$	$U$	$W$
Optimal regime*	4.33	12.2	21.6	0.17	4.76	0.00	4.55	-0.01	0.62	1.39	2.02
$\phi=0, \chi=0.166$	1.90	14.7	39.3	0.10	8.07	0.00	4.57	0.02	0.58	1.41	1.97
$\phi=0.085, \chi=\phi$	8.47	0.00	12.1	0.29	1.21	0.04	19.1	0.01	0.62	1.37	1.99

\* In the optimal regime  $(\phi, \chi)=(0.043, 0.166)$ .

Interestingly, the second row of Table 7 shows that banks would voluntarily raise some of their TLAC in the form of equity ( $e=0.019$ ) but not as much as it would be socially optimal ( $e=0.043$ ). The chosen value of  $e$  reflects that banks internalize the impact of equity funding on risk shifting incentives and, through it, on the pricing of bail-in debt—a clear ‘market discipline’ effect. Yet such value is lower than the socially optimal one because the losses caused to the DIA are not internalized. In any case, as shown in the relevant columns of the table, the size of the DI subsidy with TLAC of 16.6% is quite small for any  $\phi$  and the welfare losses from the sub-optimal choice of  $\phi$  are significant but not enormous (around 5bps of bank assets).

Finally, in the third row of Table 7, we consider how the optimal regulatory regime would change if bail-in debt were not considered as a possible source of loss absorbing capacity and the only regulatory tool were the capital requirement ( $\phi=\chi$ ). In this setup the optimal loss absorbing buffer is considerably smaller than the unrestricted optimum, just 8.5% instead of 16.6%. This leads to higher bank default in both the risky and the safe state. The reason for the smaller buffer lies in the agency costs of outside equity. Increasing  $\phi$  leads to a dilution of insiders’ ownership  $\gamma$  and boosts their private benefit taking  $\Delta$ . On the positive side, risk shifting declines ( $\varepsilon$  falls to less than a quarter of its baseline value) but the overall risk of defaulting on deposits (which can be inferred from the size of  $DI$ ) increases relative to the unconstrained optimal regime due to the size of the total loss absorbing buffer. All in all, the impact of restricting the bank to only build buffers using common equity is to reduce social welfare in an amount equivalent to 3bps of bank assets.

### 4.2.2 Marginal effects of the TLAC requirements

Figure 1 shows how key variables from the bank’s optimal capital structure problem change as a function of the TLAC requirement  $\chi$  while the capital requirement remains fixed at the value of 4.3% that it has in the optimal regime. The most important effect of increasing  $\chi$  is to reduce the unconditional probability of defaulting on insured deposits,  $\bar{P} = (1-\varepsilon)P_0 + \varepsilon P_1$ , called ‘Default Probability’ in this and subsequent figures. The fall in  $\bar{P}$  is due entirely to the mechanical protection provided by the loss-absorbing buffers. In fact, increasing  $\chi$  pushes the bank to use expensive bail-in debt instead of cheaper deposits, damaging its profitability and, with it, insiders’ incentives regarding  $\Delta$  and  $\varepsilon$ . As a result, the two underlying agency problems worsen, although quantitatively these effects are relatively small.

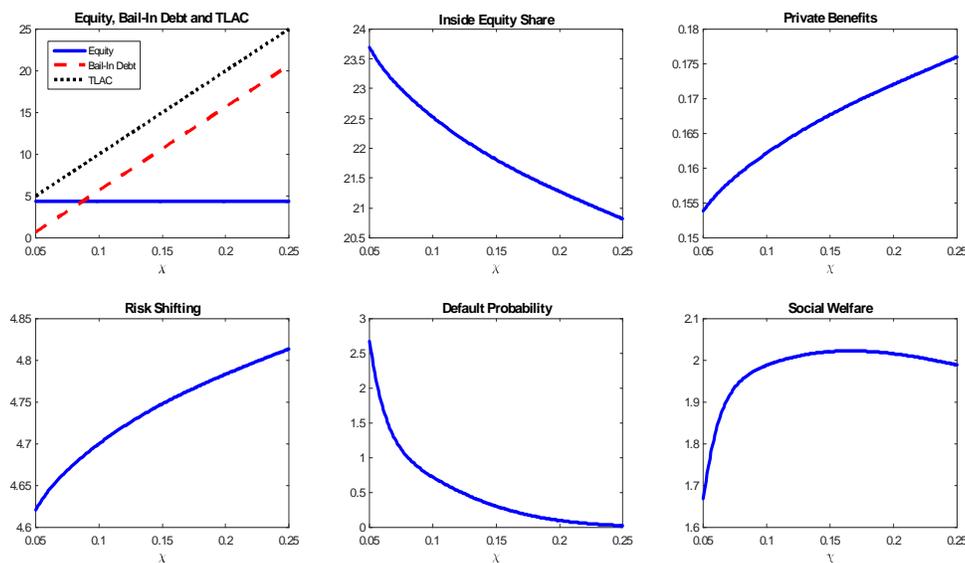


Figure 1: Equilibrium outcomes as a function of the TLAC requirement  $\chi$

The bottom right panel in the figure shows our measure of social welfare —the social value of the bank  $W$ — which obviously reaches its maximum when  $\chi$  equals its previously identified optimal value of 16.6%. It is interesting to notice that social welfare deteriorates significantly when the TLAC requirement falls below 10%, while the fall in welfare when  $\chi$

moves further above its socially optimal value happens more slowly. At that stage, the loss comes from missing additional liquidity value from insured deposits, which is related to the calibrated value of the (net) liquidity convenience yield (71bps).

### 4.2.3 Marginal effects of the capital requirement

Figure 2 describes the effects of varying the capital requirement  $\phi$  while keeping the TLAC requirement at its optimal value of 16.6%.

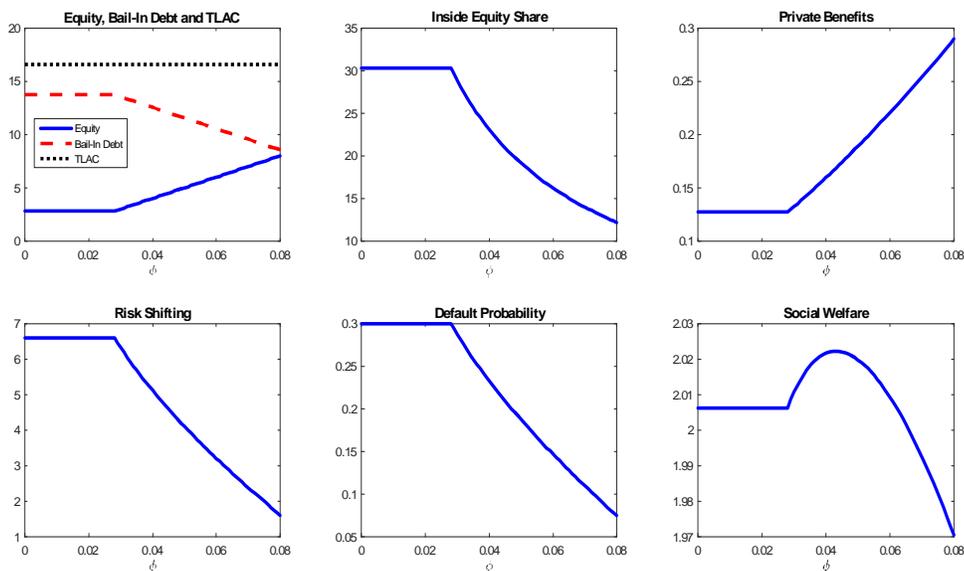


Figure 2: Equilibrium outcomes as a function of the capital requirement  $\phi$

The top left panel shows that when  $\phi$  is lower than about 3%, the capital requirement is no longer binding as the bank voluntarily opts for an equity buffer of about 3%. Above such level, rising  $\phi$  produces dilution in insiders' ownership, increasing their private benefit taking. However, as already identified in prior discussions, risk shifting falls, which explains the fall in the unconditional probability of defaulting on deposits. The bottom right panel of the figure reflects the implications for social welfare, which is maximized when  $\phi$  equals its previously identified optimal value of 4.3%.

## 5 Comparative statics

In this section we examine how the optimal capital and TLAC requirements and the equilibrium outcomes associated with them, change in response to variations in relevant parameters of the model. The results help better understand the qualitative trade-offs behind our core quantitative results.

### 5.1 Sensitivity to the return cost of risk shifting ( $h_1$ )

Figure 3 shows the socially optimal arrangement and its associated equilibrium outcomes change as  $h_1$  increases from 20% below the baseline value to 20% above. This parameter is directly related to the return cost of risk shifting and, hence, inversely related to the severity of this agency problem. Other things equal, both risk shifting and its social cost fall with  $h_1$ . Increases in  $h_1$  are then optimally accommodated with declines in the capital requirement  $\phi$  (as the marginal importance of risk shifting declines) and the TLAC requirement  $\chi$  (as there is less of a reason to sacrifice the liquidity value of deposit funding).

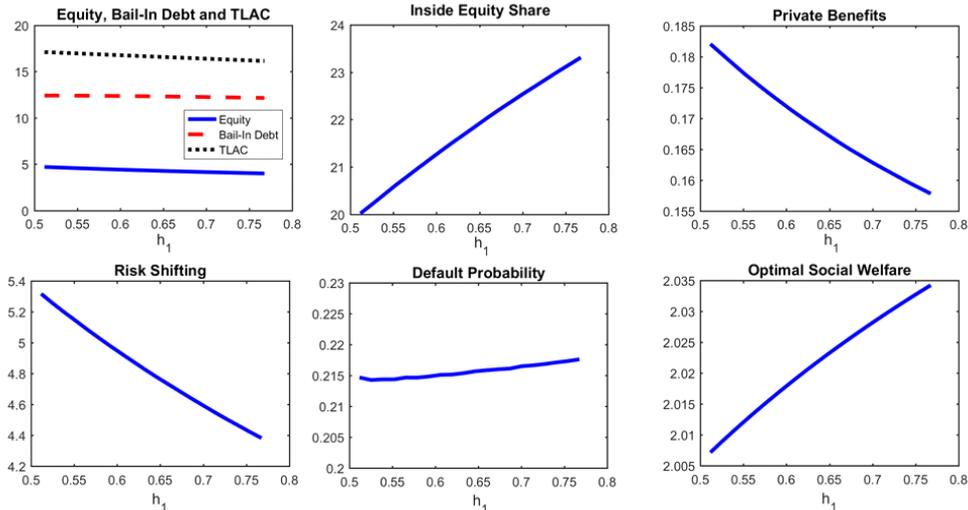


Figure 3: Sensitivity of the optimal regulatory ratios and related outcomes to  $h_1$

Interestingly, when  $h_1$  increases, the trade-off between providing insiders with incentives not to shift risk and not to take private benefits improves. Specifically, reducing  $\phi$  allows

insiders' ownership to be increased, which implies that private benefit taking can also be reduced. Welfare increases but, somewhat paradoxically, the unconditional probability that the bank defaults on its deposits,  $\bar{P}$ , slightly increases.

## 5.2 Sensitivity to the volatility of asset returns ( $\sigma_0$ and $\sigma_1$ )

Figure 4 shows how the optimal regulatory ratios and the implied equilibrium outcomes respond to changes in the variance of asset returns. Because this variance is different across risk states, we explore the case in which the baseline values of  $\sigma_0$  and  $\sigma_1$  get multiplied by a same factor  $\sigma$ , which is depicted on the horizontal axes. So with  $\sigma=1$  we have the baseline where the optimal capital requirement is around 4.3% and the optimal TLAC ratio is 16.6%. On most of the explored range, increasing  $\sigma$  increases the levels of both requirements.

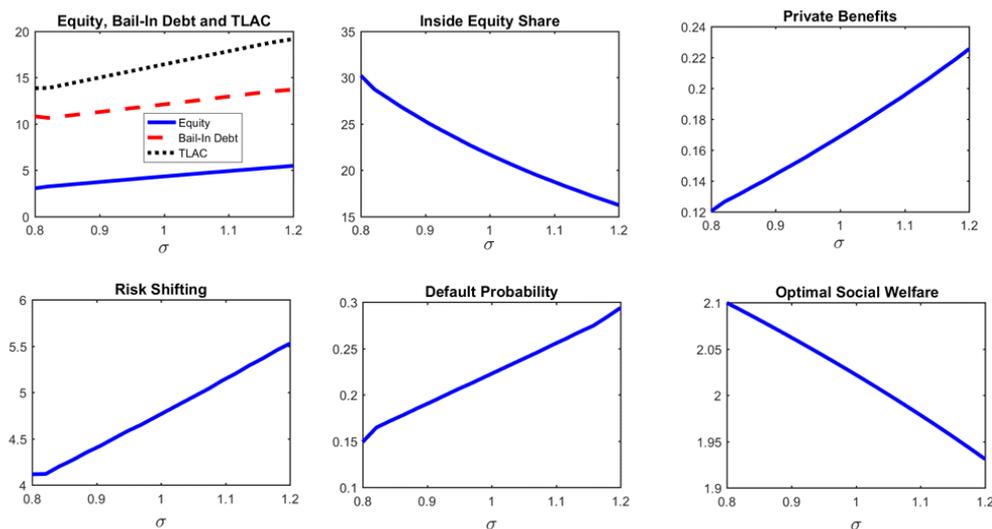


Figure 4: Sensitivity of the optimal regulatory ratios and related outcomes to  $\sigma_i$

Increasing the variance of asset returns rises the exogenous risk faced by the bank and, other things equal, its probability of default. This increases the incidence of the deadweight default costs suffered by the DIA. It is then optimal to impose a higher TLAC requirement  $\chi$ . In parallel, the greater exogenous risk makes insiders' temptation to shift risk stronger, calling for a larger capital requirement  $\phi$ . However, increasing the capital requirement re-

duces insiders' share in total equity and pushes them into greater private benefit taking, so eventually the two agency problems worsen as  $\sigma$  increases. Even after optimally adjusting the regulatory ratios, welfare decreases and the unconditional probability of bank failure increases.

### 5.3 Sensitivity to the value of private benefit taking ( $g_1$ )

Figure 5 shows the implications of changing the parameter  $g_1$  which measures the size of the private gains that insiders may get by increasing  $\Delta$ . So from a private perspective and other things equal, a larger  $g_1$  means that insiders will be tempted to divert more resources from the bank. From a social perspective, however, such diversion implies a lower net social value loss when  $g_1$  is higher. The results show that the social planner responds to the prospects of larger  $\Delta$  by increasing the TLAC requirement  $\chi$  (which explains the fall in the unconditional probability of defaulting on deposits,  $\bar{P}$ ) and its bail-in debt component,  $\chi - \phi$ , but less aggressively so than if (increased) value of private benefits were not considered part of the social surplus generated by the bank. This last fact explains why social welfare increases with  $g_1$  over a significant range of values of this parameter.

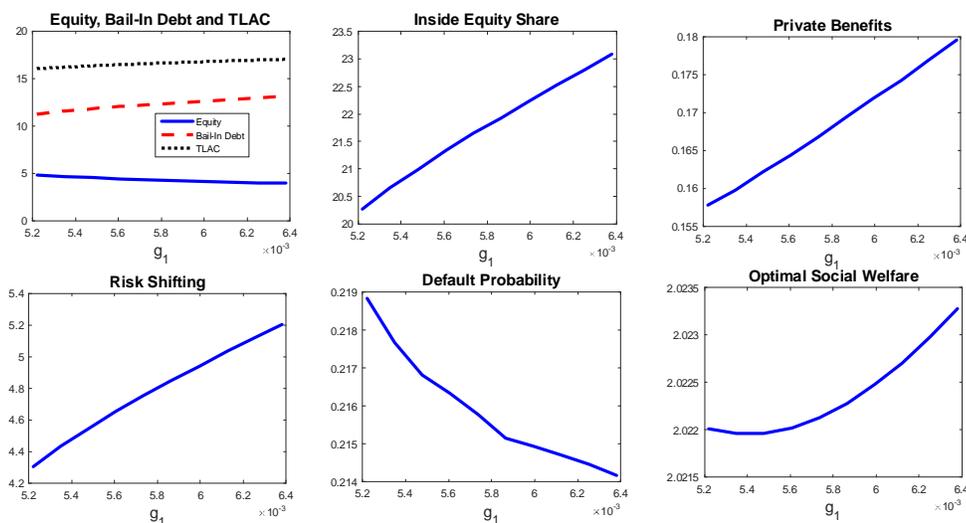


Figure 5: Sensitivity of the optimal regulatory ratios and related outcomes to  $g_1$

## 5.4 Sensitivity to the deadweight costs of bank default ( $\mu_d$ )

Figure 6 shows the impact of varying the deadweight costs of defaulting on insured deposits  $\mu_d$ . As might be expected, the optimal TLAC requirement  $\chi$  is increasing in  $\mu_d$ , while the optimal capital requirement is barely sensitive to  $\mu_d$ . Intuitively, replacing insured deposits with bail-in debt reduces the probability of defaulting on the former, thus avoiding the corresponding deadweight loss. However, such substitution increases funding costs and, thus, reduces the profitability of the bank. The lowering profitability increases the dilution of insiders' ownership needed to raise any given amount of outside equity and, hence, worsen the private benefit taking problem. The social planner counteracts this problem by making the additional buffers to consist fully of bail-in debt (thus tolerating a slight deterioration of the risk shifting problem).

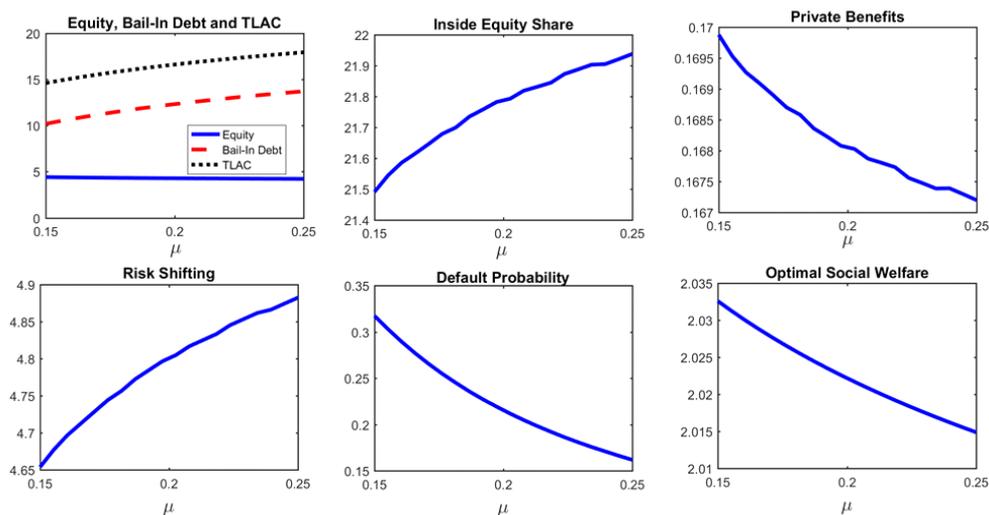


Figure 6: Sensitivity of the optimal regulatory ratios and related outcomes to  $\mu_d$

## 5.5 Sensitivity to deposits' liquidity convenience yield ( $\psi$ )

Figure 7 shows the effects of changing the liquidity convenience yield of insured deposits  $\psi$ . The most direct effects of this parameter are to increase bank profitability and the social opportunity cost of reducing deposit funding (i.e. rising the TLAC requirement  $\chi$ ). Other

things equal, the rise in profitability has a positive impact on the two underlying incentive problems and makes the social planner more willing to reduce  $\chi$  and to tolerate a rise in the probability of bank default. In fact both effects reinforce each other, as the decline in  $\chi$  has additional positive effects on profitability and incentives, which in turn reduces the need for large regulatory buffers. As  $\psi$  and  $\chi$  falls, the relative marginal importance of the two agency problems gets slightly altered, inducing a small increase in  $\phi$  and a decline in risk shifting. The U-shaped relationship between private benefit taking  $\Delta$  and  $\psi$  is explained by the combined impact of the profitability effect (which tends to reduce  $\Delta$ ) and the dilution of insiders' ownership eventually caused by the rise in  $\phi$  (which tends to increase  $\Delta$ ).

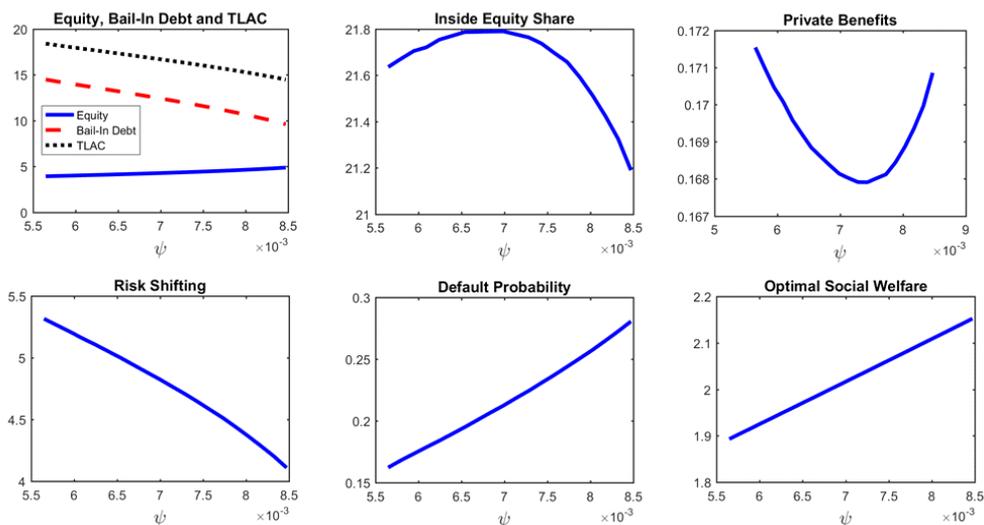


Figure 7: Sensitivity of the optimal regulatory ratios and related outcomes to  $\psi$

## 6 Extensions

### 6.1 Deadweight losses from bail-in debt write-offs

For the baseline results, we have assumed that the deadweight costs from writing off bail-in debt,  $\mu_b$ , are zero. We made this assumption mainly because of the inexistence of evidence allowing us to calibrate  $\mu_b$ . In Table 8 we show the sensitivity of the results to this parameter.

Table 8: Optimal policy with deadweight losses on bail-in debt (%)

	$e$	$b$	$\gamma$	$\Delta$	$\varepsilon$	$P_0$	$P_1$	$DI$	$T$	$U$	$W$
$\mu_b=0.00^*$	4.33	12.2	21.6	0.17	4.76	0.00	4.55	-0.01	0.62	1.39	2.02
$\mu_b=0.03$	7.67	1.76	13.3	0.27	1.82	0.01	16.6	0.01	0.63	1.38	1.99
$\mu_b=0.06$	8.39	0.21	12.2	0.29	1.27	0.04	18.8	0.01	0.62	1.37	1.99
$\mu_b=0.09$	8.47	0.00	12.1	0.29	1.21	0.04	19.1	0.01	0.62	1.37	1.99

\* The optimal requirements under each  $\mu_b$  can be found as  $\phi=e$  and  $\chi=e+b$ .

The importance of bail-in debt in the optimal regulatory regime,  $\chi - \phi$ , declines sharply with  $\mu_b$ . In parallel, the optimal capital requirement increases but not enough to avoid a sizeable fall in  $\chi$ . For a small positive value of  $\mu_b$  such as 3%, the total buffer size declines from 16.6% to 8.5% and bail-in debt declines from 12.2% to 1.8%. Equity is used much more intensively and, as a result, the losses associated with private benefit taking increase significantly. On the positive side, the higher equity ratio leads to a large reduction in risk taking as evidenced by the big decline in  $\varepsilon$ . Further increases in  $\mu_b$  gradually lead to the complete elimination of bail-in debt from the optimal capital structure. When  $\mu_b=0.09$  the overall buffer is 8.47% while bail-in debt is not used at all.

## 6.2 Systemic costs of bank default

We can also extend the analysis to the case of a systemic bank by assuming that its default on insured deposits causes external or system-wide costs equal to a proportion  $\mu_{ed}$  of its initial assets. With these costs into account, the social value of the bank in (18) needs to be modified to

$$W = U + T - DI - EC, \quad (21)$$

where

$$EC = \beta \sum_{i=0,1} \varepsilon_i [\mu_{ed}(1 - F(w_i - \sigma_i)) + \mu_{eb}(F(w_i - \sigma_i) - F(s_i - \sigma_i))]. \quad (22)$$

Table 9: Optimal policy with social costs of defaulting on deposits (%)

	$e$	$b$	$\gamma$	$\Delta$	$\varepsilon$	$P_0$	$P_1$	$DI$	$EC$	$T$	$U$	$W$
$\mu_{ed}=0.0$	4.33	12.2	21.6	0.17	4.76	0.00	4.55	-0.01	0.00	0.62	1.39	2.02
$\mu_{ed}=0.5$	4.06	18.5	22.2	0.17	5.08	0.00	0.96	-0.04	0.02	0.61	1.35	1.98
$\mu_{ed}=1.0$	3.94	20.6	22.6	0.16	5.23	0.00	0.51	-0.04	0.01	0.61	1.34	1.98

Table 9 above shows that the main impact of introducing a social cost associated with the default of the bank on its deposits is to dramatically increase the size of the overall buffers to values that approach 25% in the  $\mu_{ed} = 1.0$  case. Interestingly, when we allow for values of  $\mu_{ed}$  larger than zero, the model prescribes an even lower capital requirement than in the baseline (4% when  $\mu_{ed} = 0.5$ ). This happens for two reasons. First, substituting cheaper deposits for more expensive bail-in debt reduces profits and makes insiders more inclined towards private benefit taking. In parallel, the low probability of default makes the underlying deposit insurance subsidy very small, counteracting insiders' larger incentives to shift risk. As a result, the optimal capital requirement falls, making equity represent an even lower share of TLAC than in the baseline model.

## 7 Conclusions

The increase in capital requirements and the revision of regulation regarding non-equity liabilities such as bail-in debt that may provide banks with total loss-absorbing capacity (TLAC) are two important aspects of the deep reform of bank solvency regulation undertaken in the aftermath of the global financial crisis. Yet surprisingly little research has been done on the optimal size and composition of TLAC.

In this paper we build a banking model in the spirit of Merton (1977) and insert in it a number of frictions, including two relevant agency problems. The result is a framework which we think is useful for the analysis of banks' capital structure and its optimal regulation. Our banks have the possibility to issue deposits that are a cheap source of funding due to the fact that they provide a liquidity convenience yield to their holders. However, defaulting on these deposits produces large social deadweight costs. Hence, this model assigns an important role

to liabilities with loss-absorbing capability (such as common equity, bail-in debt and other possible components of TLAC), even if these liabilities are inferior to deposits in terms of liquidity provision.

In our model, equity and bail-in debt are perfect substitutes in their role as a protection against deadweight losses from bank default but greatly differ in their impact on incentives. Bank insiders take two unobservable decisions based on self-serving motives but which have implications for other stakeholders and for society at large. One decision concerns risk shifting (exposing the bank to riskier but lower on average asset returns) and the other concerns private benefit taking (extracting utility from the bank to the detriment of its asset returns).

These two agency problems bring in the key trade-off driving the optimal composition of banks' TLAC. Incentivizing banks to restrain their risk shifting requires that the loss-absorbing buffer is mainly made up of equity. This is because, intuitively, bail-in debt counts like debt in terms of inviting equity holders to gamble. However, following the analysis of Innes (1990), forcing banks to issue large amounts of outside equity has the disadvantage of reducing insiders' equity share, which pushes them into excessive private benefit taking. The optimal composition of TLAC is determined by trading off these two competing agency problems. Under our calibration of the model, the optimal regulatory regime features a large TLAC requirement (16.6% of assets) and a significant though limited capital requirement (4.3%), therefore assigning a very important role to bail-in debt (12.3%).

The intuition for the sparing use of equity financing under our baseline calibration is that, once overall buffers are large enough to make the bank relatively unlikely to default on its insured deposits, private benefit taking becomes a more serious threat to the social value of the bank than risk shifting. Private benefit taking reduces bank efficiency and leads to deadweight losses. In contrast, when imposing losses on bail-in debt carries no deadweight costs, risk shifting mainly leads to redistribution between equity and bail-in debt holders (which can be compensated for by paying a high interest rate on TLAC eligible debt).

As extensions to the baseline model, we have explored the sensitivity of these results to

introducing a deadweight loss associated with the write-off of bail-in debt and some external social costs due to the bank's default on its deposits. As one might expect, if inducing losses on bail-in debt involves deadweight losses, the attractiveness of this form of TLAC declines very sharply, and the optimal regulatory regime approaches one in which TLAC is much lower and entirely made of equity. In contrast, if the bank's default on its deposits causes system-wide cost, the optimal loss absorbing buffer increases, with a composition if anything more tilted towards bail-in debt.

## Appendix: Derivation of formulas for $E$ , $J$ , $T$ and $DI$

**Formula for the value of equity  $E$**  Investors' risk neutrality implies that the overall value of equity can be found as

$$E = \beta \sum_{i=0,1} \varepsilon_i E_i - T, \quad (23)$$

where  $E_i = E(\max\{\tilde{R}_i - B, 0\})$  are residual equity payoffs gross of corporate taxes,  $B = R_d d + R_b b$  are total promised repayments to deposits and bail-in debt, and  $T$  is the present value of expected corporate tax payments. Using (1), we can write

$$\begin{aligned} E_i &= E(\max\{(1 - \Delta - h(\varepsilon))R_a \exp(\sigma_i z - \sigma_i^2/2) - B, 0\}) \\ &= (1 - \Delta - h(\varepsilon))R_a \int_{\bar{z}_i}^{\infty} \exp(\sigma_i z - \sigma_i^2/2) f(z) dz - B(1 - F(\bar{z}_i)), \end{aligned} \quad (24)$$

where  $f(z)$  and  $F(z)$  are the density and CDF of a  $N(0, 1)$  random variable, and  $\bar{z}_i$  is implicitly defined by  $(1 - \Delta - h(\varepsilon))R_a \exp(\sigma_i \bar{z}_i - \sigma_i^2/2) - B = 0$ , so

$$\bar{z}_i = \frac{1}{\sigma_i} [\ln B - \ln(1 - \Delta - h(\varepsilon)) - R_a + \sigma_i^2/2].$$

Now, the fact that  $f(z) = \frac{1}{\sqrt{\pi}} \exp(-z^2/2)$  allows us to write

$$\begin{aligned} \int_{\bar{z}_i}^{\infty} \exp(\sigma_i z - \sigma_i^2/2) f(z) dz &= \int_{\bar{z}_i}^{\infty} \frac{1}{\sqrt{\pi}} \exp(\sigma_i z - \sigma_i^2/2 - z^2/2) f(z) dz \\ &= \int_{\bar{z}_i}^{\infty} \frac{1}{\sqrt{\pi}} \exp(-(z - \sigma_i)^2/2) f(z) dz \\ &= \int_{\bar{z}_i - \sigma_i}^{\infty} \frac{1}{\sqrt{\pi}} \exp(-\frac{1}{2}y^2) f(y) dy = 1 - F(\bar{z}_i - \sigma_i), \end{aligned}$$

where the last line follows from the change of variable  $y = z - \sigma_i$ .

Finally, using the symmetry of the normal distribution and prior definitions we have that  $1 - F(\bar{z}_i - \sigma_i) = F(\sigma_i - \bar{z}_i) = F(s_i)$  and  $1 - F(\bar{z}_i) = F(-\bar{z}_i) = F(s_i - \sigma_i)$ , so (24) can be expressed as

$$E_i = (1 - \Delta - h(\varepsilon)) R_a F(s_i) - B F(s_i - \sigma_i), \quad (25)$$

which substituted into (23) yields (10).

**Formula for the joint value of equity and bail-in debt  $J$**  To obtain the expression for the joint value of equity and bail-in debt,  $J$ , we can similarly write

$$J = \beta \sum_{i=0,1} \varepsilon_i J_i - T, \quad (26)$$

with

$$J_i = E(\max\{\tilde{R}_i - R_d d, 0\}) - \mu_b E(\xi(\tilde{R}_i - B < 0) \max\{\tilde{R}_i - R_d d, 0\}),$$

where  $\xi(\tilde{R}_i - B < 0)$  is an indicator function taking value 1 when the condition  $\tilde{R}_i - B < 0$  holds. So the term multiplied by  $\mu_b$  accounts for the deadweight losses incurred if the bank does not default on insured deposits but fails to pay its bail-in debt in full.

Reproducing the steps followed for the derivation of (25), we can find

$$J_i = [(1 - \Delta - h(\varepsilon)) R_a F(w_i) - R_d d F(w_i - \sigma_i)] - \mu_b ((1 - \Delta - h(\varepsilon)) R_a [F(w_i) - F(s_i)]), \quad (27)$$

where

$$w_i = \frac{1}{\sigma_i} [\ln(1 - \Delta - h(\varepsilon)) + \ln R_a - \ln R_d - \ln d + \sigma_i^2/2], \quad (28)$$

justifying equations (13) and (14) in the main text.

**Formula for the value of the corporate taxes paid by the bank  $T$**  Corporate taxes are proportional to EAI as long as EAI are positive and zero otherwise. EAI in state  $i$  are given by the difference between the net return on assets and the net cost of debt liabilities:

$$\begin{aligned} EAI_i &= (\tilde{R}_i - 1) - [(R_d - 1) + p] d - (R_b - 1) b \\ &= \tilde{R}_i - (R_d d + R_b b) - (1 + p d - d - b) \\ &= \tilde{R}_i - B - e, \end{aligned}$$

where the second equality follows from having  $B = R_d d + R_b b$  and the banks' balance sheet constraint at  $t = 0$ , which implies  $e + b + d = 1 + p d$ . Thus the expected present value of corporate taxes can be written as

$$T = \beta \sum_{i=0,1} \varepsilon_i T_i, \quad (29)$$

where

$$\begin{aligned} T_i &= \tau E(\max\{EAI_i, 0\}) \\ &= \tau E(\max\{\tilde{R}_i - B - e, 0\}). \end{aligned}$$

Following steps similar to those leading to (25), we can find

$$T_i = \tau [(1 - \Delta - h(\varepsilon)) R_a F(t_i) - (B + e) F(t_i - \sigma_i)], \quad (30)$$

where

$$t_i = \frac{1}{\sigma_i} [\ln(1 - \Delta - h(\varepsilon)) + \ln R_a - \ln(B + e) + \sigma_i^2/2], \quad (31)$$

which substituted in (29) yields (15).

**Formula for the net value of the deposit insurance liability  $DI$**  To derive the expression for  $DI$  in (17), it is convenient to start with the special case in which  $\mu_d = \mu_b = 0$ . In such case  $DI$  is given by

$$DI_{|\mu_d=0} = \beta \sum_{i=0,1} \varepsilon_i (R_d d - D_i) - pd, \quad (32)$$

where  $D_i = E(\min\{R_d d, \tilde{R}_i\})$  represents the expected value of the bank's final payments on deposits under  $\mu = 0$ , taking into account that the bank defaults on them when  $\tilde{R}_i < R_d d$ , paying back  $\tilde{R}_i$  rather than  $R_d d$ .

Now, given that  $\min\{R_d d, \tilde{R}_i\} = \tilde{R}_i - \max\{\tilde{R}_i - R_d d, 0\}$ , we can write

$$D_i_{|\mu_d=0} = E(\tilde{R}_i) - J_{i|\mu_b=0}. \quad (33)$$

But then, substituting  $E(\tilde{R}_i) = (1 - \Delta - h(\varepsilon))R_a$  and (27) in (33), we find

$$D_i_{|\mu_d=0} = R_d d F(w_i - \sigma_i) + (1 - \Delta - h(\varepsilon)) R_a (1 - F(w_i)), \quad (34)$$

where the first and second terms account for the bank's payments on deposits in non-default states and default states, respectively.

Plugging (34) into (32) and reordering yields

$$DI_{|\mu=0} = \beta \sum_{i=0,1} \varepsilon_i [R_d d (1 - F(w_i - \sigma_i)) - (1 - \Delta - h(\varepsilon)) R_a (1 - F(w_i))] - pd. \quad (35)$$

In the general case with  $\mu_d \geq 0$  and  $\mu_b \geq 0$  the only required adjustment is to add to  $DI$  the expected deadweight losses incurred when the bank defaults on insured deposits, which are  $\mu_d (1 - \Delta - h(\varepsilon)) R_a (1 - F(w_i))$  in each state  $i$ . Adding them to (35) leads to (17).

## References

- Allen, F., and D. Gale (2000), *Comparing Financial Systems*, Cambridge, MA: MIT Press.
- Bassett, W., Lee, S. and Spiller, T. (2012), “Estimating changes in supervisory standards and their economic effects,” Finance and Economics Discussion Series 2012-55, Federal Reserve Board, Washington D.C.
- Bennett, R. L., and H. Unal (2014), “Understanding the components of bank failure resolution costs,” FDIC CFR Working Paper.
- Begenau, J. (2015), “Capital requirements, risk choice, and liquidity provision in a business cycle model,” Harvard Business School Working Paper No. 15-072.
- Berger, A., and E. Bonaccorsi (2006), “Capital structure and firm performance: A new approach to testing agency theory and an application to the banking industry,” *Journal of Banking & Finance* 30, 1065–1102.
- Black, F., and M. Scholes (1973), “The pricing of options and corporate liabilities,” *Journal of Political Economy* 81, 637–654.
- Boyd, J., and H. Hakenes (2014), “Looting and risk-shifting in banking crises,” *Journal of Economic Theory*, 149, 43–64.
- Calomiris, C., and C. Kahn (1991), “The role of demandable debt in structuring optimal banking arrangements,” *American Economic Review* 81, 497–513.
- Caprio, G., L. Laeven, and R. Levine (2007), “Governance and bank valuation,” *Journal of Financial Intermediation* 16, 584–617.
- Diamond, D., and P. Dybvig (1983), “Bank runs, deposit insurance, and liquidity,” *Journal of Political Economy* 91, 401–419.
- Diamond, D., and R. Rajan (2005), “Liquidity shortages and banking crises,” *Journal of Finance* 60, 615–647.
- Financial Stability Board (2015), “Principles on loss-absorbing and recapitalisation capacity of G-SIBs in resolution: Total loss-absorbing capacity (TLAC) term sheet,” 9 November, available at <http://www.fsb.org/wp-content/uploads/TLAC-Principles-and-Term-Sheet-for-publication-final.pdf>
- French, K., M. Baily, J. Campbell, J. Cochrane, D. Diamond, D. Duffie, A. Kashyap, F. Mishkin, R. Rajan, D. Scharfstein, R. Shiller, H. Shin, M. Slaughter, J. Stein, and R. Stulz (2010), *The Squam Lake Report: Fixing the Financial System*. Princeton University Press.

- Flannery, M. (2005), “No pain, no gain? Effecting market discipline via reverse convertible debentures,” in *Capital Adequacy Beyond Basel: Banking, Securities, and Insurance*, edited by H. S. Scott, 171–96. Oxford: Oxford University Press.
- Holmstrom, B., and J. Tirole (1997), “Financial intermediation, loanable funds, and the real sector,” *Quarterly Journal of Economics* 112, 663–691.
- Innes, R. (1990), “Limited liability and incentive contracting with ex-ante action choices,” *Journal of Economic Theory* 52, 45–67.
- Ip, G. (2016), “The perverse effects of crisis-prevention bonds,” *Wall Street Journal Blogs*, 3 March, available at <http://blogs.wsj.com/economics/2016/03/03/the-perverse-effects-of-crisis-prevention-bonds/>
- Jensen, M., and W. Meckling (1976), “Theory of the firm: Managerial behavior, agency costs and ownership structure,” *Journal of Financial Economics*, 3, 305–60.
- Kareken, J., and N. Wallace (1978), “Deposit insurance and bank regulation: A partial-equilibrium exposition,” *Journal of Business* 51, 413–438.
- Kashyap, A., R. Rajan, and J. Stein (2008), “Rethinking capital regulation,” in *Maintaining Stability in a Changing Financial System*, 431–471. Federal Reserve Bank of Kansas City.
- Laeven, L., and F. Valencia (2010), “Resolution of banking crises: the good, the bad and the ugly,” IMF WP/10/146.
- Martynova, N., and E. Perotti (2014), “Convertible bonds and bank risk-taking,” University of Amsterdam.
- McDonald, R. (2013), “Contingent capital with a dual price trigger,” *Journal of Financial Stability* 9, 230–241.
- Merton, R. (1977), “An analytic derivation of the cost of deposit insurance and loan guarantees: An application of modern option pricing theory,” *Journal of Banking & Finance* 1, 3–11.
- Pennacchi, G. (2010), “A structural model of contingent bank capital,” FRB of Cleveland WP No. 10-04.
- Pennacchi, G., T. Vermaelen, and C. Wolff (2014), “Contingent capital: The case of CO-ERCs,” *Journal of Financial and Quantitative Analysis* 49, 541–574.
- Stiglitz, J., and A. Weiss (1981), “Credit rationing in markets with imperfect information,” *American Economic Review* 71, 393–410.

Sundaresan, S. and Wang, Z. (2015), “On the design of contingent capital with a market trigger,” *Journal of Finance* 70, 881–920.

Van den Heuvel, S. (2008), “The welfare costs of bank capital requirements,” *Journal of Monetary Economics* 55, 298–320.