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

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January 2018

Abstract

We assess quantitatively the optimal size and composition of banks' total loss absorbing capacity (TLAC) in the presence of a trade-off between the liquidity services provided by deposits and the deadweight costs from defaulting on them. The optimal composition of TLAC reflects the relative importance of the incentive problems best dealt with by using equity (risk shifting) or bail-in debt (private benefit taking). We find that TLAC size in line with current regulation is appropriate and an important fraction of it should consist of bail-in debt, but only if the deadweight losses from haircutting such debt are small.

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

JEL codes: G21, G28, G32

*We are grateful for the feedback received from seminar participants at Baffi-Carefin Conference on Supervision, Market Discipline and the Challenge of Bank Profitability, Bank of England Conference on the Interaction of Regulatory Instruments, BCBS-RTF Conference on the Impact of Banking Regulation on Financial Markets, CEMFI Workshop on Financial Stability, CEPR Spring Finance Symposium, ESCB Day-ahead Conference in Vienna, De Nederlandsche Bank, European Central Bank, OxFIT 2017, University of Zurich, and the XXIV Finance Forum. We especially thank Christoph Bertsch, Florian Bösser, Falko Fecht, Simas Kucinskas, Andrés Mesa, Robert Marquez, Jean-Charles Rochet, Caspar Siegert, Suresh Sundaresan, Ansgar Walther, and Tanju Yorulmazer for valuable comments and suggestions, and Ewelina Zurowska and Johannes Pöschl for superb research assistance.

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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 lead 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 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 take a loss 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.

We use a standard Merton-type model of a bank and add to it two agency frictions which will shape the key capital structure trade-offs faced by the bank and its regulator. The bank is run by controlling shareholders (called insiders) 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.[1] As established in the literature, the risk shifting incentives 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).

Putting both elements together intuitively produces trade-offs that potentially lead to interior solutions. However, it is not possible to obtain unambiguous analytical results since all depends on the relative importance of the distortions (Hellwig, 2009). Hence, in this paper we take a quantitative route, doing our best to calibrate the parameters on the basis of direct and indirect evidence on US banks.

In order to ensure the quantitative relevance of the predictions, the model incorporates additional departures from the ideal conditions of Modigliani-Miller. First, we assume that insured deposits provide a liquidity convenience yield to investors, so that, other things equal, they are a cheaper source of funding to the bank than bail-in debt.[2] Second, we assume that defaulting 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. Therefore bail-in debt in the model is uninsured debt with three distinctive features: it is junior to insured deposits; it provides no special liquidity services to its holders; it implies lower deadweight losses in case of default.[3] For realism, the model also includes a deposit insurance premium, paid on a flat rate basis per unit of deposits, and corporate taxes levied on banks' positive earnings after interest.

The result is what, to a first approximation, might be seen as a double-decker model in

[1] This description implies abstracting from the potential conflict of interest between the controlling shareholders and the managers. So, when applying the model to a large banking organization, our insiders can be thought of as the coalition between controlling shareholders and managers.

[2] 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. Deposit insurance is present in most countries as a guarantee on retail deposits and a protection against bank runs.

[3] Specifically, in the baseline calibration we assume that defaulting on deposits causes deadweight resolution costs equal to a positive proportion of the assets repossed 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.

which the (socially) optimal size of the bank's TLAC (equity plus bail-in debt) is mainly determined by the trade-off between the liquidity services provided by deposits and the deadweight costs of defaulting on them, while the (privately or socially) optimal composition of such TLAC is mainly determined by the relative importance of the two agency problems.[4] There are, however, interesting connections between the two deckers. For instance, when asset returns are more volatile and the risk shifting problem is more severe, debt finance, either in the form of insured deposits or bail-in debt, is more costly so the socially optimal level of TLAC and the part of it consisting of equity simultaneously increase. Or if the liquidity yield of insured deposits increases, the socially optimal TLAC diminishes, while the part of it consisting of equity simultaneously increases (so as to offset the otherwise increased costs of risk shifting).

We calibrate the model by matching a large set of key moments from US banking and financial data and then examine its quantitative 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 requirements since banks would otherwise choose to operate with no buffers to take maximum advantage of the corresponding guarantees (Kareken and Wallace, 1978).[5] 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 baseline results –obtained under the assumption that defaulting on bail-in debt involves zero deadweight losses– 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 to make the 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

[4] As insiders neglect the cost of defaulting on insured deposits, the privately optimal size of TLAC is zero except for unrealistically high deposit insurance premia.

[5] This is so under the calibrated value of the deposit insurance premium. As acknowledged in the literature, the bank's incentive to lever up excessively would disappear under a sufficiently higher premium and could be controlled with alternative means such as, for instance, a deposit insurance premium increasing in the bank's leverage.

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 redistributional impact (from bail-in debt holders to equity holders) which is compensated, in equilibrium, via the pricing of bail-in debt.[6] As discussed in an extension, the last result gets modified if defaulting on bail-in debt is costly. In such a case, the socially optimal capital buffer increases while the socially optimal TLAC requirement decreases significantly and bail-in debt plays a very limited loss-absorbing role.

Our paper belongs to the novel and growing field of quantitative banking, which includes contributions such as Van den Heuvel (2008), Bhattacharya et al. (2015), Davila and Goldstein (2016), Mankart, Michaelides and Pagratis (2017), Kashyap, Tsomocos and Vardoulakis (2017), Segura and Suarez (2017), among others. As several of the models in this field (and differently from what is common in macroeconomics), we abstract from dynamics because the goal is to quantify the trade-offs that determine banks' privately and socially optimal capital structures rather some dynamic responses to shocks.

Initial discussions on banks' loss-absorbing liabilities different from equity 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 extant 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 (Sundaresan and Wang, 2015), discouraging risk shifting (Pennacchi, 2010; Martynova and Perotti, 2017), or providing committment capacity in a resolution context (Walther and

[6] In contrast, in the absence of the buffer provided by bail-in debt, risk shifting would make deposits overly exposed to default, causing disproportionate deadweight losses.

White, 2016).

Most of these papers study the effects of adding an ad hoc amount of contingent convertibles to some predetermined bank capital structure (often in substitution for part of the uninsured debt). Our paper differs from them in that it focuses on the loss-absorbency (rather than contingent convertibility) of 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. Conceptually, 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.[7]

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 explore extensions of the model in which defaulting on bail-in debt involves deadweight losses and in which bank default causes external systemic costs. Section 6 contains the conclusions. Appendix A provides the derivation of the mathematical formulas used in the analysis. Appendix B analyzes the sensitivity of the baseline quantitative results to the key parameters of the model.

2 The Model

This section describes the ingredients of the model, the capital structure problem solved by the bank, and the expression for net social surplus relevant for the normative analysis.

[7] Papers in the above-mentioned literature typically abstract from agency problems between inside and outside equityholders. So their models 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.

2.1 Ingredients of the model

We consider a bank owned by a group of risk-neutral shareholders who, to sharpen the presentation, are assumed to be penniless and yet essential to manage the bank; we call them the *insiders*.[8] The bank is 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 private benefit taking decision Δ and (b) a risk shifting decision ε.[9]

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

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

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 σ_i, which switches depending on the risk state i.[10] We assume $\sigma_0 < \sigma_1$ so that $i = 0$ represents a *safe state* and $i = 1$ represents a *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 ε and, hence, is directly controlled by insiders' unobservable risk shifting decision $\varepsilon \in [0, 1]$. The function $h(\varepsilon)$, increasing and convex in ε, 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).

[8] As further pointed out below (footnote 14), the analysis could be trivially extended to consider the case in which insiders are endowed with some wealth that they can use to finance the bank. All the results qualitatively go through if such wealth is small relative to the loss-absorbency buffer needed by the bank.

[9] Given that we focus the analysis on a single bank, the risk state i can be thought of as indistinctly capturing idiosyncratic or aggregate factors affecting bank performance. In the latter case, ε could be thought of as the exposure of the individual bank to an aggregate risky state rather than directly the probability of such state.

[10] 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.

Insiders' unobservable private benefit taking diminishes expected asset returns by a fraction Δ 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 private benefits $g(\Delta)$ and their consumption c at $t = 1$:

$$U = g(\Delta) + \beta c, \tag{2}$$

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

Bank assets are financed with endogenously determined amounts of insured deposits d, uninusured bail-in debt b, and common equity e, all raised from outside investors. Outside investors are also risk neutral and have the same subjective discount factor β as the insiders, but they are 'deep pockets' and, hence, able to supply funds elastically at an expected gross rate of return equal to $1/\beta$. 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 common equity is a standard limited-liability claim on the residual cash flow of the bank at $t = 1$. Importantly, insured deposits provide a per-unit liquidity convenience yield ψ at $t = 1$ to their holders, who are then willing to accept a gross deposit rate R_d equal to $1/\beta - \psi$.

We denote the fraction of common equity sold to outside investors by γ, which means that the insiders retain the remaining fraction $1 - \gamma$. So insiders' financial payoffs at $t = 1$ have the form of a fraction $1 - \gamma$ of common equity payoffs. This is consistent with considering insiders' compensation as (realistically) junior to the repayment obligations associated with deposits and bail-in debt but implies constraining attention to simple linear sharing rules for the division of the residual payoffs between the insiders and the outside equityholders.[11]

[11] Instead of a linear sharing rule, an optimal contract might involve some endogenous nonlinearity in equity returns, which would complicate the numerical solution of the model. We think that the linear sharing rule is not a bad approximation under the assumption, also used in the calibration, that the relevant insiders

When the asset returns $\tilde{R}$ at $t = 1$ are insufficient to pay $R_d d$ to insured depositors, the bank is insolvent. In such a case, the 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 μ_d is a deadweight asset-repossession cost. The DIA charges a premium p per unit of deposits at $t = 0$ and offsets any surplus/deficit in its budget at $t = 1$ with lump sum transfers to/from taxpayers.

Since the bail-in debt is junior to insured deposits, the bank may fail to pay it in full without defaulting on deposits. This happens when $R_d d < \tilde{R} < R_d d + R_b b$. In these cases, bail-in debt pays off $(1 - \mu_b) \max\{\tilde{R} - R_d d, 0\}$, where $\mu_b \leq \mu_d$ is a deadweight asset-repossession cost.[12]

The bank is subject to two regulatory constraints: (a) a minimum capital requirement which imposes that its equity e must be at least a fraction ϕ of its risky assets, that is, $e \geq \phi$, and (b) a minimum TLAC requirement which imposes that loss-bearing liabilities (equity or bail-in debt) must be at least a fraction $\chi \geqslant \phi$ of its risky assets, that is, $e + b \geq \chi$.[13] So, out of total loss-bearing liabilities, at least a fraction ϕ 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 (including the one currently applicable to US banks), a tax rate τ is levied on positive earnings after interest (EAI) at $t = 1$.

2.2 The bank's capital structure problem

At date 0, prior to making their unobservable risk shifting and private benefit taking decisions, Δ and ε, the bank insiders establish an overarching contract with the outside investors. The contract fixes the capital structure of the bank as described by e and b, the fraction of bank equity retained by the insiders γ, the (gross) interest rates promised by bail-in debt R_b

include controlling shareholders in a broad sense rather than just executives (whose compensation based on stock options might indeed involve nonlinearities).

[12] 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 in order to pay its bail-in debt.

[13] As in reality, both requirements are set in terms of the book value of the corresponding items at $t = 0$.

and insured deposits R_d and, implicitly, the insiders' subsequent unobservable choices of Δ and ε. The corresponding contract problem can be formally described as follows:

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

subject to:

$$(1-\gamma)\,E \geq e \qquad [PC^e] \tag{4}$$

$$J-E \geq b \qquad [PC^b] \tag{5}$$

$$\beta(R_d+\psi) \geq 1 \qquad [PC^d] \tag{6}$$

$$(\Delta,\varepsilon) = \arg\max\nolimits_{(\Delta',\varepsilon')}\, \gamma E + g\left(\Delta'\right) \qquad [IC] \tag{7}$$

$$e \geqslant \phi \qquad [CR] \tag{8}$$

$$e+b \geqslant \chi \qquad [TLAC] \tag{9}$$

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 at $t=0$ of the common equity and the 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, $U=g(\Delta)+\gamma E$, which equals the private benefits obtained from the control of bank assets, $g\left(\Delta\right)$, plus the present value of their equity stake, γE. 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).[14] The constraints also include (7) which is the incentive compatibility condition describing how insiders decide on Δ and ε once the contract is in place.[15] Finally (8) and (9) reflect the existence of a minimum capital requirement ϕ and a minimum TLAC requirement χ.

[14] 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 $(1-\gamma)\,E \geq e-w$.

[15] If the solutions in (Δ,ε) are interior, (7) can be replaced, as usual, with the first order conditions associated with each of the choice variables.

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:

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

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

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

$B = R_d d + R_b b$ 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 $e + b + d = 1 + pd$:[16]

$$d = \frac{1 - e - b}{1 - p}. \tag{12}$$

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.

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

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

where

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

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.[17] The term multiplied by μ_b accounts for the deadweight losses incurred

[16] For simplicity, we assume that pd is paid and recorded as an expense after the bank's compliance with the regulatory requirements has been checked at $t = 0$. Otherwise, the bank's book value of equity relevant for regulatory purposes would decline to $e - pd$ and the expression for the requirements in (8) and (9) would become unnecessarily convoluted.

[17] The presence of bail-in debt, $R_b b$, makes $B > R_d d$ and hence $s_i < w_i$.

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

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

where

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

and $F(t_i - \sigma_i)$ is the probability with which the bank obtains positive EAI (and hence pays positive taxes) in state i.[18] 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.

2.3 Deposit insurance costs and the social value of the bank

The presence of the safety net for depositors implies the existence of a liability for the DIA, the so-called Merton Put (Merton, 1977). After netting the deposit insurance premium paid by the bank at $t = 0$, the expected present value of the DIA's deficit (or surplus) that taxpayers will cover (or receive) if positive (negative) at $t = 1$ is:

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

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

$$W = U + T - DI, \tag{18}$$

so it is determined by the surplus accruing to the bank's insiders, U, the revenue from the corporate taxes paid by the bank, T, and the net cost of deposit insurance to the taxpayers, DI. Other stakeholders (namely the outside investors investing in deposits, bail-in debt or equity) simply break-even when their participation constraints in (4)-(6) are binding, as they happen to be in equilibrium, so they make no surplus contribution to (18).

[18] 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.

3 Calibration

The calibration of the model strives to make its quantitative predictions empirically relevant. We calibrate the parameters either directly, by relating them to available data or existing empirical evidence, or indirectly, by finding values that allow the model-implied moments to match their counterparts in the data. Table 1 displays the baseline parameter values, briefly referring to how each parameter is calibrated. The only parameters not previously introduced are 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 β 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. This 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. The ex post real interest rate is computed by subtracting CPI inflation from the nominal yield.

Table 1: Baseline parameter values (one period = one year)*

Investors' discount factor	β	0.983	risk-free rate: 1.65% [1]
Deposits' liquidity convenience yield	ψ	0.0071	cost-adjusted spread T-bill - deposit yields [1]
Gross return on bank assets (if Δ=ε=0)	R_a	1.03	real cost-adjusted interest earned on assets [1]
Deadweight loss from default on deposits	μ_d	0.20	Bennet-Unal 2014 (FDIC resolutions 1986-2007)
Deadweight loss from default on bail-in debt	μ_b	0.00	(no evidence so far)
Deposit insurance premium	p	0.0006	2.5-9bps for CAMELS 1&2 (FDIC after 2011)
Corporate tax rate	τ	0.25	Damodaran database, financials' average rate
Capital requirement (CET1)	ϕ	0.04	minimum Tier 1 capital (T1) in Basel II
TLAC requirement (CET1 + other TLAC)	χ	0.08	minimum T1 + Tier 2 capital (T2) in Basel II
Private benefit level parameter [2]	g_1	0.0058	inside ownership 17.2% (Berger-Bonaccorsi 2006)
Private benefit elasticity parameter	g_2	0.1669	56.3% buffer-adjusted share T1/(T1+T2) [1]
Private benefit extra curvature parameter	g_3	0.15	arbitrary (technical, unimportant in equilibrium)
Cost of risk shifting parameter	h_1	0.2894	5% annual crisis probability
Risk shifting elasticity parameter	h_2	2.2103	d(Z-score)/de=0.2 (Laeven-Levine 2010)
Asset risk in the safe state	σ_0	0.0319	0.05% normal-times failure rate (arbitrary, small)
Asset risk in the risky state	σ_1	0.1145	20% crises failure rate (Laeven-Valencia 2010)

Notes: [1] US data, 1985-2006. [2] Functional forms: $g(\Delta) = g_1\Delta^{g_2} - g_3\Delta$ and $h(\varepsilon) = h_1\varepsilon^{h_2}$.

The liquidity convenience yield ψ is set by matching the difference between the average return on 3-month Treasury bills and the average return on bank deposits after adjusting for the bank's costs of deposit-taking activities.[19] To find these returns, we also use data for 1985-2006. 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 asset-side activities. If all of the non-interest expenses were linked to asset-side activities, the liquidity premium would be around 140bps. At the other extreme, if 2/3 of the costs were attributed to deposit-taking, the liquidity premium would be zero. The calibrated value of 70.6bps is the mid-point of this range, which implies attributing 1/3 of non-interest expenses to the provision of deposit services.

To calibrate the asset return R_a, we also use FDIC data for 1985-2006, we compute the average nominal return earned on bank assets as Total Interest Income over Total Assets and subtract from it the CPI inflation rate and the 2/3 of non-interest expenses attributted to asset-side activities. This gives a real cost-adjusted rate of return on bank assets of 3.16% per annum, which explains the calibrated value of R_a.

The bankruptcy cost parameter for insured deposits μ_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, μ_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 in Section 5.

We set the capital requirement ϕ 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 χ, we set it equal to 0.08 in line with the Tier 1 plus Tier 2 capital

[19] In particular, we take the difference between Treasury yields and deposit rates as a measure of a 'gross ψ' that reflects depositors' willingness to pay for the liquidity services provided by deposits and obtain a 'net ψ' by subtracting from it the imputed cost of providing those liquidity services. We feed all the model formulas with such 'net ψ'.

requirement in Basel II, assuming that the type of liabilities other than common equity that qualify as Tier 2 capital (preferred stock and subordinated debt) have loss-absorbing capacity similar to that currently foreseen for bail-in debt.

We treat the DI premium p as a flat-rate premium. In the US the DI premium charged on each bank depends on its CAMELS rating. However, Bassett, Lee and Spiller (2012) document 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 it is very hard to make the DI premium p truly risk-sensitive *ex ante*. So we set p equal to 6 bps, in line with the premium paid by US banks in Risk Category I (CAMELS ratings 1 and 2) since 2011.[20] In fact, under our calibration, the bank's model-implied Z-score is close to 3.3 which is consistent with attaining a CAMELS rating 1 or 2.[21]

The bank corporate tax rate τ is set equal to 25% in line with the average tax rate for financials reported in the data set maintained by Aswath Damodaran.[22]

The private benefits function is specified as follows:

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

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

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

[20] 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

[21] The Z-score is conventionally defined as (ROA+Equity Ratio)/(Standard Deviation of ROA), which in model terms we can measure as Z-score= $\sum_{i=0,1} \varepsilon_i \{[(1-\Delta-h(\varepsilon)) R_a - 1] + (e+b)\}/\sigma_i$ where i indexes the risk state and we interpret the Equity Ratio broadly as the share of all loss absorbing liabilities, $e+b$, in the initial assets.

[22] See http://www.stern.nyu.edu/~adamodar/pc/datasets/taxrate.xls.

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

In the absence of directly observable or external estimates for the private benefit parameters (essentially, g_1 and g_2), the cost of risk shifting parameters (h_1 and h_2), and the asset return volatilities in the safe and risky states (σ_0 and σ_1), we set them in order to match six data moments.[23] 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 six targets.[24] Conceptually, each of the targets can be mainly associated with one of the parameters (that we indicate in parenthesis in the list below), although formally the six parameters are found jointly as just described.

Target 1 (g_1). We set a target for the fraction of bank equity owned by insiders (γ) of 17.2% based on Berger and Bonaccorsi (2006), who study US banks over the 1990-95 period. Such target relies on a broad definition that includes, additional to direct management and close family ownership (9.3%), the stake of institutional shareholders and other large shareholders (7.9%) who can effectively hold management to account.

Target 2 (g_2). To parameterize the curvature of the $g(\Delta)$ function, we target the share of Tier 1 Capital in Total Capital after adjusting for voluntary buffers. 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%.[25]

Target 3 (h_1). For calibration purposes, we will interpret the 'risky state' in the model

[23] We arbitrarily set g_3 equal to 0.025. It can be show that g_3 has a small effect on the shape of the function $g(\Delta)$ at low values of Δ (which are the economically relevant ones) but a significant effect at large values, helping the numerical solution method to avoid corner solutions.

[24] The procedure is performed with the Nelder-Meade algorithm as implemented in the Matlab function fminsearch.m.

[25] Thus, the target capital ratio is very close to the baseline minimal capital requirement. In fact, the capital requirement is binding in the baseline solution of the model, which means that it would be easier to match the remaining targets if the capital ratio were allowed to be lower than the regulatory minimum.

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 (ε) that matches the observed frequency of banking crises in the US. From 1900 to 2016, the US has experienced four banking crises implying a crisis probability of around 3% per annum.[26] 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, which is the moment we target.[27]

Target 4 (h_2). To parameterize the curvature of the $h(\varepsilon)$ function, we use the evidence in Laeven and Levine (2009) who estimate that the derivative of banks' Z-score with respect to the capital ratio is equal to 0.2, with a standard deviation of 0.09. We compute the numerical derivative of the bank's Z-score with respect to ϕ around the baseline parameterization and aim to match it with its point estimate in Laeven and Levine (2009).[28]

Targets 5 (σ_0) and 6 (σ_1). We match the probability of bank failure generated by the model in 'normal times' ($P_0 = 1 - F(w_0 - \sigma_0)$) and 'risky times' ($P_1 = 1 - F(w_1 - \sigma_1)$) with the observation that the failure of major banks in normal times is very rare (so we target a very low 0.05% default rate in the safe state) and the evidence in Laeven and Valencia (2010) on bank defaults during crises. They analyze bank failures during the last financial crisis and find that US banks experiencing formal bankruptcy held no more than 6% of total US bank deposits. However, if one defines bank failure as receiving large scale government assistance, the fraction of total deposits at 'failed' banks reaches values above 20%. Adopting this broader definition of bank failure, we target a bank default rate of 20% in the risky state.

[26] Those were the 1907 crisis, the Great Depression, the Savings and Loan Crisis and the recent Global Financial Crisis.

[27] In reference to international evidence, Schularick and Taylor (2012) state: "The frequency of crises in the 1945–71 period was virtually zero, when liquidity hoards were ample and leverage was low; but since 1971, as these hoards evaporated and banks levered up, crises became more frequent, occurring with a 4% annual probability."

[28] See footnote 21 for a definition of the model-implied Z-score.

4 Quantitative Results

Table 2 below summarizes the solution to the bank's capital structure problem under the baseline parameters values. The values of many variables equal or are very close to the targets set in the calibration of the parameters. For the equity retained by bank insiders (γ), the solution is higher than the targeted 17.2%, but is still in line with the international evidence. Specifically, the value is consistent with Caprio, Laeven and Levine (2007), who use a sample of 244 banks from 44 countries and report average cash flow rights for banks' ultimate controlling owners of 26%.

The results regarding the decisions directly affected by agency problems imply that the reduction in asset returns due to private benefit taking (Δ) and risk shifting ($h(\varepsilon)$) amount around 0.15% and 0.04% of total bank assets, respectively. So direct agency costs under our baseline calibration are significant but small relative to deadweight default losses.

The unconditional expected value of the deposit insurance subsidy, DI, is around 0.19% of total bank assets which implies that deposit insurance is underpriced. Specifically, deposit insurance premia cover well the liabilities of the DIA in the safe state but not in the less likely risky state, where they represent about 3.4% of bank assets while deposit insurance premia are only about 0.055% of bank assets. These numbers are 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. 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 $\mu_d > 0$ incurred whenever the bank defaults on its deposits.

Insiders' overall payoff U amounts to around 1.5% of bank assets, of which equity payoffs represent about 1.3% of bank assets and private benefits the remaining 0.2%. Finally, the net social surplus generated by the bank W equals 1.94% of bank assets. This is higher than the private surplus U, reflecting that the average corporate taxes T paid by the bank (0.64% of bank assets) substantially exceed the average net deposit insurance subsidy DI (0.19% of 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	γ	24.2
Asset returns lost due to private benefit taking (%)	Δ	0.15
Asset returns lost due to risk shifting (%)	$h(\varepsilon)$	0.04
Probability of the risky state realizing (%)	ε	5.02
Bank Z-score (as defined in footnote 21)	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

4.1 Examining the role of agency costs

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. Later on we study the socially optimal capital and TLAC requirements when both of them are present.

4.1.1 The model without agency costs

To analyze the case in which Δ and ε are fully contractible, we solve the problem stated in (3)-(9) without imposing (7). Table 3 shows the solution to the bank's capital structure problem for different levels of the capital and TLAC requirements, ϕ and χ. As a reference, the first row of the table reports the results under the baseline regime with ϕ=0.04 and χ=0.08. In the last row of the table we present the results under the capital and bail-in debt requirements that maximize social welfare in this special case.

Table 3: Effects of regulation with no agency costs (%)

	e	b	γ	Δ	ε	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
ϕ=χ=0.08	8.00	0.00	13.8	0.03	1.44	0.06	19.7	0.03	0.67	1.53	2.18
ϕ=0,χ=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 (ϕ, χ)=(0.04,0.08). ** In the optimal regime ϕ=χ=0.098.

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, Δ is extremely low compared to the outcome under the baseline calibration with the full model. Equally, the full contractibility of the bank's risk choice ε results in a low value of 2.1% per annum. Nevertheless, ε remains above its asset return maximizing value of zero because the bank still has an incentive to take excessive risk in order to enjoy the DI subsidy. In other words, the contract that maximizes insiders' value 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.[29]

The next row in the table examines the consequences of forcing the bank to use only common equity (ϕ=χ=0.08). More 'skin in the game' for shareholders leads to a smaller exposure to the risky state (ε falls to 1.4% per annum), while the lower reliance on debt leads to a slight increase in the corporate tax bill. Thus the private value of the bank (U) declines while its social value (W) rises relative to the baseline regulatory regime. In contrast, removing the requirement to issue any common equity (ϕ=0, χ=0.08) increases U and decreases W. This happens because, by using bail-in debt as the only loss absorbing liability, the bank economizes on corporate taxes but increases its risk shifting choice ε, to the detriment of the DIA.

The final row shows the optimal regulatory regime in this version of the model, which re-

[29] Of course, in the case when Δ and ε are observable, the regulator could directly regulate those. In this case, it could set the first best value of Δ and $\varepsilon = 0$, 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 ϕ and χ as in the full model where Δ and ε are unobservable.

lies exclusively on capital (ϕ=χ=0.098). Making the loss-absorbing buffer entirely composed of common equity reduces insiders' risk shifting incentives dramatically (ε falls to 0.02%) and turns DI negative, so that the DIA obtains a surplus. The optimal total buffer size trades off liquidity convenience yield versus deadweight default costs. Further increases in ϕ could drive ε even closer to zero but at the cost of further reducing the supply of insured deposits (and sacrificing the corresponding liquidity convenience yield), which makes them socially unworthy.

While bank owners would prefer a buffer entirely made of bail-in debt, due to its tax advantages, common equity is preferred from a social standpoint because the latter is more effective in keeping insiders' risk shifting incentives under control. 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.

4.1.2 Risk shifting only

In this second special case, we only shut down the agency problem associated with private benefit taking: we assume that the choice of Δ is fully contractible, while the risk shifting choice ε 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 ε.

Table 4: Effects of regulation with uncontractible risk shifting only (%)

	e	b	γ	Δ	ε	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
ϕ=χ=0.08	8.00	0.00	14.7	0.03	1.44	0.06	19.7	0.03	0.67	1.53	2.18
ϕ=0,χ=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 (ϕ, χ)=(0.04,0.08). ** In the optimal regime ϕ=χ=0.098.

Under the baseline regulatory regime, the model with only risk shifting distortions works similarly to the full model. The TLAC requirement is binding in order to take maximum advantage of the liquidity yield associated with insured deposits. The capital requirement is binding because higher leverage allows the bank to pay lower taxes and maximize the value of the Merton put.

The next row examines the consequences of making the requirement exclusively based on common equity (ϕ=χ=0.08). This leads the bank to reduce dramatically its risk taking. The net cost of deposit insurance DI declines considerably, mainly due to saving on bank default costs. As a result, social surplus W increases substantially while the private value of the bank U only falls slightly.

The third row demonstrates the consequences of leaving the buffer composition entirely to the bank's discretion (ϕ=0,χ=0.08). Opting for outside equity financing would be a way for insiders to commit not to shift too much risk ex post. However, given that the costs of risk shifting are mainly suffered by the DIA, insiders' privately optimal choice of e is rather small, risk shifting is very large (with ε higher than 9%), and the social surplus generated by the bank is much lower than in any of the other rows.

The socially optimal regulatory regime for this special case, which appears in the fourth row of the table, relies exclusively on the capital requirement (ϕ=χ=0.098). Similarly to Table 4, a high capital ratio pushes risk shifting close to zero and brings the social surplus W very close to its value in the case in which both Δ and ε were contractible.

4.1.3 Private benefit taking only

To examine the case in which only the private benefit taking decision Δ is unobservable, we solve the problem stated in (3)-(9) with a version of (7) in which insiders' only private decision is Δ.

Table 5: Effects of regulation with uncontractible private benefit taking only (%)

	e	b	γ	Δ	ε	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
ϕ=χ=0.08	8.00	0.00	12.9	0.28	1.44	0.08	20.3	0.03	0.63	1.39	1.99
ϕ=0,χ=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 (ϕ,χ)=(0.04,0.08). ** In the optimal regime (ϕ,χ)=(0.002,0.136).

The first row of Table 5 presents the results under the baseline regulatory regime in this version of the model. The outcomes are similar to those emerging in the full model under the same regulation (Table 2), except for the decline of ε (which here is contractible) to 2.1%. Again ε does not fall to the surplus maximizing value of zero due to the distortions created by deposit insurance.

If regulation consists solely on a capital requirement (ϕ=χ=0.08), the bank is pushed to place more equity among outsiders, insiders' equity ownership gets diluted (γ falls) and, as a result, private benefit taking increases substantially. Intuitively, having less skin in the game leads insiders to extract a higher level of private benefits. The losses from private benefit taking eat into asset returns, the probability of bank default increases in both states, and social surplus declines substantially.

The third row explores the regime that only relies on the TLAC requirement (ϕ=0, χ=0.08). In this case, if banks can decide how to satisfy such requirement, they choose bail-in debt only. A debt based capital structure makes private benefit taking Δ to be low (less that 25% of its value under ϕ=χ=0.08) and the private and social values of the bank improve relative to the first two rows. So to a first approximation, bail-in debt works better than outside equity. However, under this regulatory regime, the residual deposit insurance distortion encourages the bank to increase its risk shifting ε to 3.4%.

This explains why the optimal regulatory regime, which appears in the fourth row of the table, involves a positive (albeit tiny) capital requirement (0.16%) and a large TLAC requirment (13.6%).[30] Essentially, by reducing the probability of defaulting on deposits (and, hence, the marginal DI subsidy), the optimal policy also reduces insiders' risk shifting incentives. In fact, an even larger loss absorbing buffer could take ε further down but this would not be socially desirable because it would involve an excessive sacrifice of the liquidity convenience yield associated with insured deposits.

[30] Of course, if ε 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.

4.2 Optimal capital and TLAC requirements in the full model

From the special cases discussed in previous sections, 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 consider the full model with both agency distortions.

Table 6: Effects of regulation in the full model (%)

	e	b	γ	Δ	ε	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
ϕ=χ=0.08	8.00	0.00	12.9	0.28	1.56	0.08	20.3	0.03	0.63	1.39	1.99
ϕ=0, χ=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 (ϕ,χ)=(0.04,0.08). ** In the optimal regime (ϕ,χ)=(0.043,0.166).

Table 6, with the same structure as the tables used in the special cases, shows that a regulatory regime with the same overall TLAC as the baseline regime but based exclusively on capital (ϕ=χ=0.08) improves in terms of social surplus over the baseline regime but is not the best solution. Specifically, it reduces risk shifting significantly (and with it the bank default costs suffered by the DIA). However, these improvements come at the cost of an increase in private benefit taking (Δ almost doubles). In the opposite extreme, imposing only a TLAC requirement (ϕ=0.0, χ=0.08), would reduce private benefit taking relative to the baseline but at the cost of increasing risk shifting (ε almost doubles). In this case, DI increases so much that makes social surplus fall dramatically relative to the baseline.

In the optimal regulatory regime (ϕ=0.043,χ=0.166), the increase in bail-in debt relative to the baseline reduces the probability of default on bank deposits quite a bit (as reflected in the decline in DI) without significantly altering the decisions subject to an agency problem (Δ increases only slightly, while ε decreases only slightly). The value of the bank to its owners (U) declines because of, among other factors, the fall in the rents associated with the convenience yield of bank deposits, which follows from the replacement of deposits with bail-in debt.

Thus, 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 somewhat 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 at the margin than private benefit taking (against which bail-in debt works better). Risk shifting still causes the return losses captured by $h(\varepsilon)$. It also exposes bail-in debt holders to the risk of experiencing haircuts in the risky state, but this risk is compensated through the endogenously high yields paid on bail-in debt.

Finally, notice that 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). This reflects that the combination of the two agency problems produces trade-offs between addressing each of them that contribute to keep the 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 ϕ=0 while keeping χ=0.166) as well as the implications of ignoring bail-in debt (making ϕ=χ) and imposing the social value maximizing capital requirement (ϕ=0.085).

Table 7: Importance of capital and bail-in debt in the optimal regime (%)

	e	b	γ	Δ	ε	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
ϕ=0, χ=0.166	1.90	14.7	39.3	0.10	8.07	0.00	4.57	0.02	0.58	1.41	1.97
ϕ=χ=0.085	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 (ϕ, χ)=(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 the voluntarily chosen value of e 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 ϕ and the welfare losses from the sub-optimal choice of ϕ 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 (ϕ=χ). In this setup the optimal loss absorbing buffer is considerably smaller than in 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 ϕ leads to a dilution of insiders' ownership γ and boosts their private benefit taking Δ. On the positive side, risk shifting declines (ε 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 decline in 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

To further explore the mechanisms underlying the explanations provided above, Figure 1 shows how key variables from the bank's optimal capital structure problem change as a function of the TLAC requirement χ 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 χ 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 χ pushes the bank to use expensive bail-in debt instead of cheaper deposits, damaging its profitability and, with it, insiders' incentives regarding Δ and ε. Hence, the two underlying agency problems worsen, although quantitatively the effects are small.

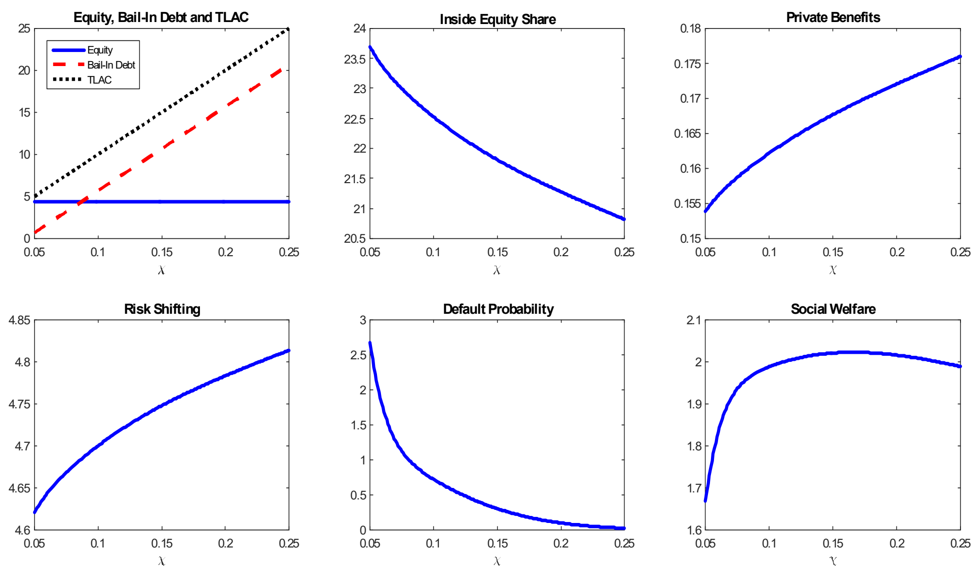

Figure 1: Equilibrium outcomes as a function of the TLAC requirement χ

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 χ equals its previously identified optimal value of 16.6%. Interestingly, W deteriorates significantly when the TLAC requirement falls below 10% (due to the increase in deadweight default losses). Instead, the fall in W when χ moves further above its socially optimal value happens more slowly (due to the loss of the liquidity convenience yield of insured deposits).

4.2.3 Marginal effects of the capital requirement

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

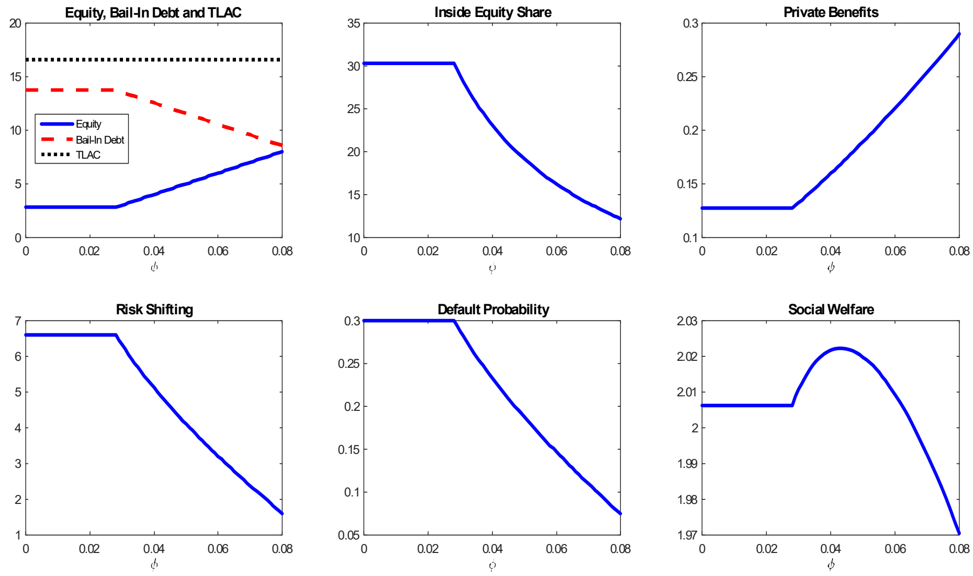

Figure 2: Equilibrium outcomes as a function of the capital requirement ϕ

The top left panel shows that when ϕ 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 ϕ 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 and the increase in welfare up to the point in which ϕ equals its previously identified optimal value of 4.3%.

5 Extensions

5.1 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, μ_b, are zero. We made this assumption mainly because of the inexistence of evidence allowing us to calibrate μ_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	γ	Δ	ε	P_0	P_1	DI	T	U	W
μ_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
μ_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
μ_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
μ_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 μ_b can be found as ϕ=e and χ=$e+b$.

The relevance of bail-in debt under the optimal regulatory regime, b, declines sharply with μ_b. In parallel, the optimal capital requirement increases but not enough to avoid a sizeable fall in χ. For a small positive value of μ_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 ε. Further increases in μ_b gradually lead to the complete elimination of bail-in debt from the optimal capital structure. When μ_b=0.09 the overall buffer is 8.47% while bail-in debt is not used at all.

The above analysis shows that the usefulness of bail-in debt rests crucially on the possibility to impose haircuts on it without suffering deadweight default costs. This explains recent regulatory efforts to reform bankruptcy proceedings and clarify the legal status of bail-in debt so as to reduce the risk of legal tangles or other costly frictions when imposing losses on its holders. For example, several European countries have created a dedicated category of 'senior non-preferred debt' on which to apply the bail-in prescriptions of the European bank resolution legislation.

5.2 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 μ_{ed} of its initial assets. To consider these costs, the social value of the bank in (18) needs to be modified to

$$W = U + T - DI - EC, \tag{21}$$

where

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

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

	e	b	γ	Δ	ε	P_0	P_1	DI	EC	T	U	W
μ_{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
μ_{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
μ_{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

* The optimal requirements under each μ_b can be found as ϕ=e and χ=$e+b$.

Table 9 above shows that the main impact of introducing an external cost associated with the default of the bank on its deposits is to dramatically increase the size of the socially optimal buffers to values that approach 25% in the $\mu_{ed} = 1.0$ case. Interestingly, when we allow for values of μ_{ed} larger than zero, the model prescribes an even lower capital requirement than in the baseline (4% when $\mu_{ed} = 0.5$), reflecting a change in the relative importance of the two agency problems around the new optimal regime. The change happens for two reasons. First, substituting cheaper deposits for more expensive bail-in debt reduces bank profits and makes insiders more inclined towards private benefit taking. In parallel, the low probability of default contributes to keep risk shifting incentives under control. As a result, the optimal capital requirement falls, making equity represent an even lower share of TLAC than in the baseline model.

6 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 relevant frictions, including two agency problems commonly included in theoretical models but rarely taken into account in quantitative models. 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 of offering 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 logic of 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 marginally more important for the social surplus generated by the bank than risk shifting.

As extensions to the baseline model, we have explored the sensitivity of the 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 costs, the optimal loss absorbing buffer increases, with a composition if anything more tilted towards bail-in debt.

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Appendices

A Derivation of the 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

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

where $E_i = \mathbb{E}(\max\{\tilde{R}_i - B, 0\})$ are residual equity payoffs gross of corporate taxes and $\mathbb{E}$ is the expectations operator. $B = R_d d + R_b b$ 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

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

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

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

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

$$E_i = (1 - \Delta - h(\varepsilon)) R_a F(s_i) - BF(s_i - \sigma_i), \tag{25}$$

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

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

with

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

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 μ_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

$$J_i = \left[(1 - \Delta - h(\varepsilon)) R_a F(w_i) - R_d d\, F(w_i - \sigma_i)\right] - \mu_b \left((1 - \Delta - h(\varepsilon)) R_a \left[F(w_i) - F(s_i)\right]\right), \tag{27}$$

where

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

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:

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

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 $e + b + d = 1 + pd$. Thus the expected present value of corporate taxes can be written as

$$T = \beta \sum_{i=0,1} \varepsilon_i T_i, \tag{29}$$

where

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

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

$$T_i = \tau \left[(1 - \Delta - h(\varepsilon)) R_a F(t_i) - (B + e) F(t_i - \sigma_i) \right], \tag{30}$$

where

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

which substituted in (29) yields (15).

Formula for the net cost of deposit insurance to taxpayers 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

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

where $D_i = \mathbb{E}(\min\{R_d d, \tilde{R}_i\})$ 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

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

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

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

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

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

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).

B Sensitivity analysis

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 and provide guidance on the dependence of the optimal regulatory regime on characteristics of the environment.

B.1 Sensitivity to the return cost of risk shifting (h_1)

Figure B1 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 ϕ (as the marginal importance of risk shifting declines) and the TLAC requirement χ (as there is less of a reason to sacrifice the liquidity value of deposit funding).

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 ϕ 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.

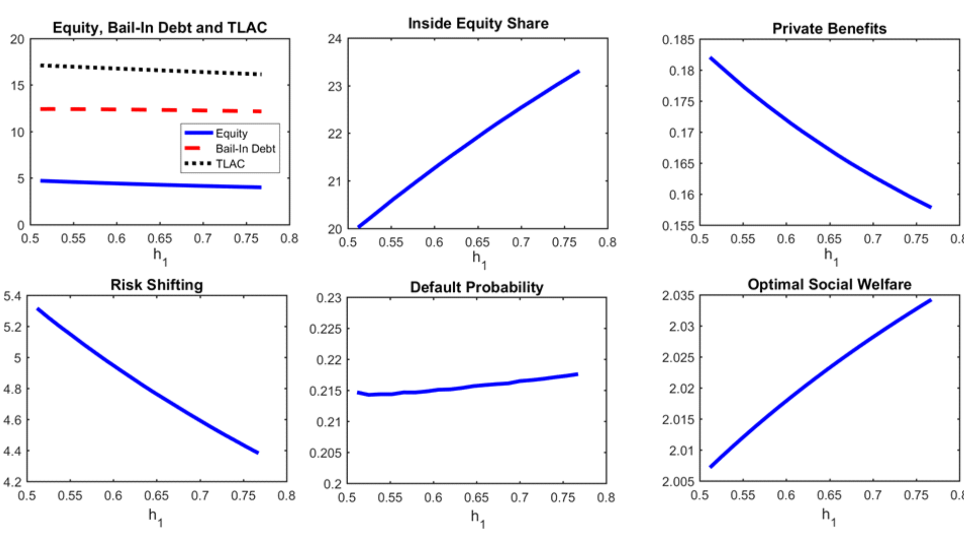

Figure B1: Sensitivity of the optimal regulatory ratios and related outcomes to h_1

B.2 Sensitivity to the volatility of asset returns (σ_0 and σ_1)

Figure B2 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 σ_0 and σ_1 get multiplied by a same factor σ, which is depicted on the horizontal axes. So with σ=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 σ increases the levels of both requirements.

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 χ. In parallel, the greater exogenous risk makes insiders' temptation to shift risk stronger, calling for a larger capital requirement ϕ. However, increasing the capital requirement reduces insiders' share in total equity and pushes them into greater private benefit taking, so eventually the two agency problems worsen as σ increases. Even after optimally adjusting the regulatory ratios, welfare decreases and the unconditional probability of bank failure increases.

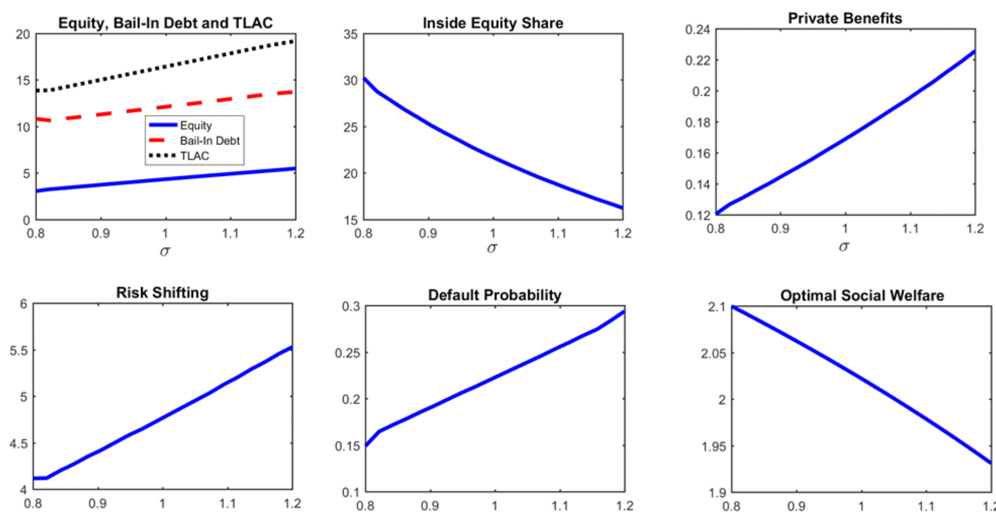

Figure B2: Sensitivity of the optimal regulatory ratios and related outcomes to σ_i

B.3 Sensitivity to the value of private benefit taking (g_1)

Figure B3 shows the implications of changing the parameter g_1 which measures the size of the private gains that insiders may get by increasing Δ. 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 Δ by increasing the TLAC requirement χ (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.

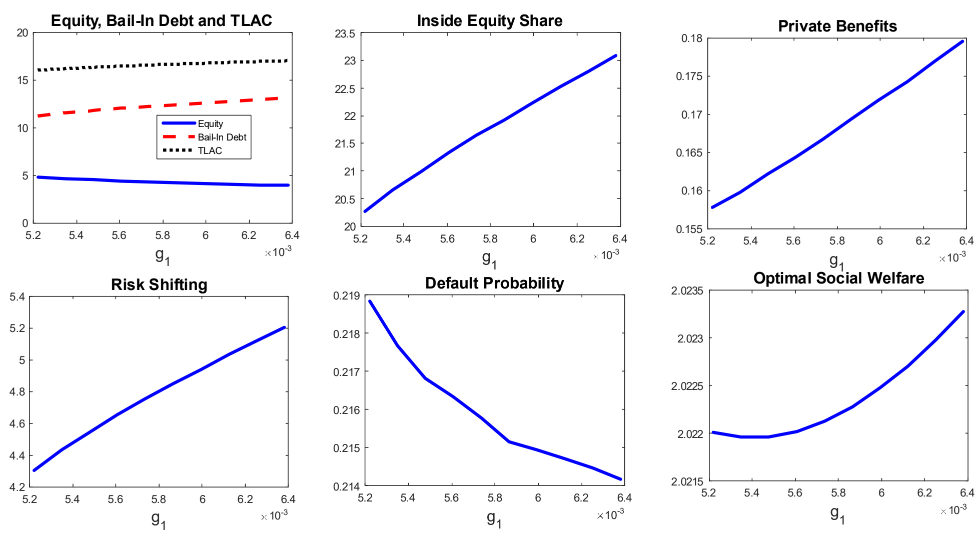

Figure B3: Sensitivity of the optimal regulatory ratios and related outcomes to g_1

B.4 Sensitivity to the deadweight costs of bank default (μ_d)

Figure B4 shows the impact of varying the deadweight costs of defaulting on insured deposits μ_d. As might be expected, the optimal TLAC requirement χ is increasing in μ_d, while the optimal capital requirement is barely sensitive to μ_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).

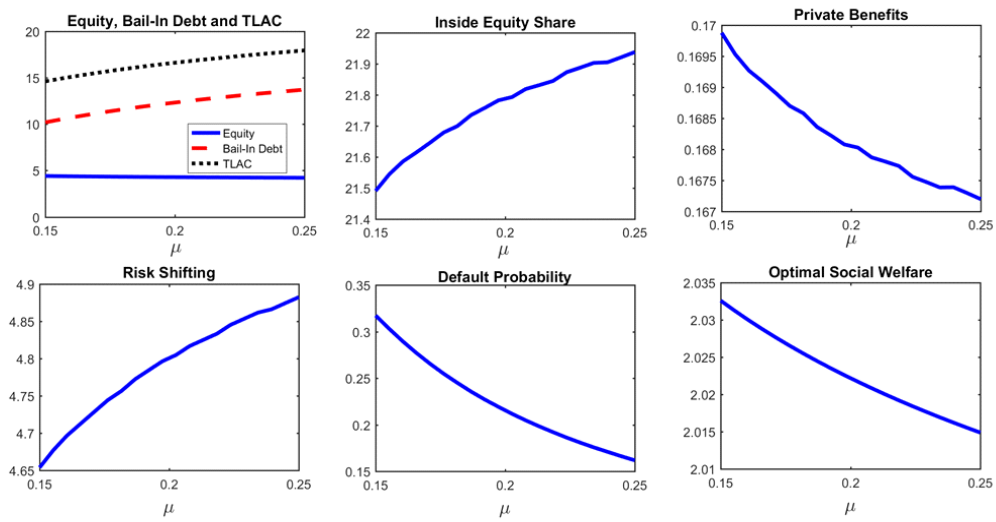

Figure B4: Sensitivity of the optimal regulatory ratios and related outcomes to μ_d

B.5 Sensitivity to deposits' liquidity convenience yield (ψ)

Figure B5 shows the effects of changing the liquidity convenience yield of insured deposits ψ. 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 χ). 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 χ and to tolerate a rise in the probability of bank default. In fact both effects reinforce each other, as the decline in χ has additional positive effects on profitability and incentives, which in turn reduces the need for large regulatory buffers. As ψ and χ falls, the relative marginal importance of the two agency problems gets slightly altered, inducing a small increase in ϕ and a decline in risk shifting. The U-shaped relationship between private benefit taking Δ and ψ is explained by the combined impact of the profitability effect (which tends to reduce Δ) and the dilution of insiders' ownership eventually caused by the rise in ϕ (which tends to increase Δ).

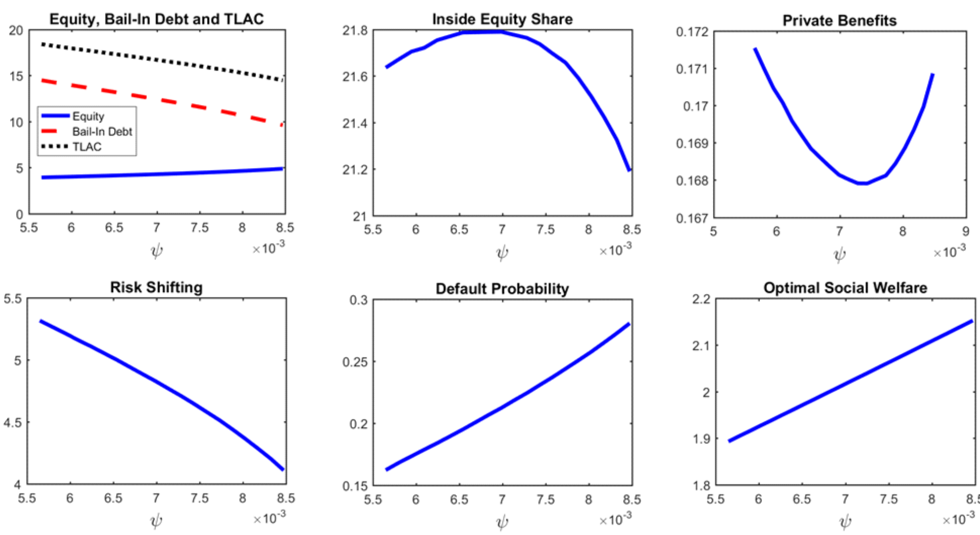

Figure B5: Sensitivity of the optimal regulatory ratios and related outcomes to ψ