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SNB Working Papers
13/2021

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SWISS NATIONAL BANK

Legal Issues

ISSN 1660-7716 (printed version)
ISSN 1660-7724 (online version)

Does the Market Believe in Loss-Absorbing Bank Debt?*

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August 3, 2021

Abstract

We propose a simple model to estimate the risk-neutral loss distribution from the credit spreads of long-term debt instruments with different seniorities. We apply our model to a sample of global systemically important banks that have issued bail-in debt in order to meet the total loss-absorbing capacity (TLAC) requirements established after the global financial crisis. Bail-in debt is a new debt category that absorbs losses in a gone-concern situation and that ranks between subordinated debt and non-eligible senior debt. With a structural model for these three debt layers, we calibrate the tail of the risk-neutral loss distribution such that it is consistent with the observed market prices. Based on this loss distribution, we find that the expected loss in a gone-concern situation exceeds TLAC for most banks and that the risk-neutral probability that TLAC will not be sufficient to cover the losses in such a situation is approximately 50%. The large expected losses that we find with our model are a consequence of the similar pricing of bail-in debt relative to other senior debt. We argue that regulators should promote further clarity about the subordination and the conversion mechanism of bail-in debt to achieve a more differentiated pricing that is more in line with regulatory expectations.

JEL Classification: G12, G28, G32

Keywords: financial stability, bank regulation, loss-absorbing capacity, creditor hierarchy, bail-in debt, bank resolution

*We thank Jürg Blum, Andreas Fuster, Dirk Tasche, and an anonymous reviewer for useful comments and suggestions and Leyla Gilgen for excellent research assistance. The views, opinions, findings, and conclusions or recommendations expressed in this paper are strictly those of the authors. They do not necessarily reflect the views of the Swiss National Bank (SNB). The SNB takes no responsibility for any errors or omissions in, or for the correctness of, the information contained in this paper. Gabriela Hrasko contributed to this paper while she was employed as scientific collaborator at the Swiss National Bank.

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1 Introduction

During the global financial crisis, authorities had no other option but to bail out systemically important financial institutions using public funds to safeguard financial stability and to avoid economic damage. After this crisis experience, the G20 leaders agreed to call on the Financial Stability Board (FSB) to end this "too-big-to-fail" (TBTF) problem. In response, the FSB published the Key Attributes of Effective Resolution Regimes for Financial Institutions (Financial Stability Board, 2014), in which it proposes that resolution authorities should have the power to write down unsecured and uninsured claims to the extent necessary to absorb losses and recapitalise firms under resolution (bail-in power). One of the main obstacles to applying this power, however, was that senior unsecured debt instruments often rank pari passu with operational liabilities, like deposits or liabilities from derivatives, for which a write down was neither credible nor feasible.

In order to overcome this problem, the FSB established a new international standard for total loss-absorbing capacity (TLAC) in resolution (Financial Stability Board, 2015). Under this standard, global systemically important banks (G-SIBs) must meet minimum requirements for TLAC by issuing a sufficient amount of bail-in debt. In order to be eligible, bail-in debt must be unsecured long-term debt that regulators can legally enforce to absorb losses prior to liabilities that are excluded from TLAC. Since 2019, advanced economy G-SIBs have to comply with this TLAC standard.

Now that banks have built-up the required loss-absorbing debt capacities, it is important to assess the credibility of the TBTF reforms from the markets' perspective. In particular, we want to answer the question whether market participants believe that G-SIBs have sufficient loss-absorbing debt to cover the expected losses in a gone-concern situation. For this purpose, it is necessary to develop a methodology that allows us to infer an expected loss given a gone-concern situation from the observed market prices of bank debt. If this loss is smaller than the loss-absorbing capacity of G-SIBs, we can argue that the TBTF reforms are credible or at least consistent with market expectations. We can also try to estimate the probability that losses in a gone-concern situation exceed the available loss-absorbing capacity. If this probability turns out to be small, we can also argue that the TBTF reforms have achieved their objectives.

In this paper, we propose a methodology to estimate the market-implied (risk-neutral) loss distribution in a gone-concern situation. From this loss distribution, we can calculate both the expected loss and the probability that losses will exceed the available loss-absorbing capacity in a gone-concern situation. Our methodology is based on a structural debt pricing model, in which we assume that bail-in debt absorbs losses prior to other senior debt, as is required by the FSB standard. With this methodology and with the disclosed amounts of loss-absorbing capacities in the regulatory loss waterfall, we estimate the risk-neutral loss distribution that is consistent with the observed credit spreads of corresponding debt instruments. The loss distribution in our model takes a parametric form with one parameter describing the risk-neutral probability of a gone-concern situation and the other parameter describing the expected loss conditional on a gone-concern situation.[1]

We find that this risk-neutral expected loss is larger than the available amount of bail-in debt for almost all banks and that the risk-neutral probability of losses exceeding the available amount of TLAC is high. The risk-neutral loss-distributions of the G-SIBs in our sample imply that in a gone-concern situation the probability of losses exceeding TLAC is approximately 50%. According to this finding, market participants doubt that the current TLAC requirements ensure sufficient loss-absorbing capacity for a gone-concern situation. They consider it likely that senior unsecured debt that does not qualify for TLAC will also be subject to losses in a gone-concern situation.[2]

The assumption that market participants believe in a clear loss waterfall is required for estimating the expected loss distribution but our policy conclusions do not depend on this assumption. Without a well-defined debt ranking, we cannot decide whether market participants price bail-in debt similar to other senior debt because they expect very high losses or because they assume that these two debt categories will often rank pari passu in gone-concern situations. However, both interpretations are a concern for the credibility of the TBTF reforms. The first interpretation is a concern because the required loss-absorbing capacity is smaller than the expected losses. The second interpretation is also a concern, because market participants do not believe that eligible bail-in debt absorbs losses prior to other senior debt instruments, as required by the TLAC standard.

Similarly, if market participants were to price senior debt very differently from bail-in debt, we would be unable to determine, without the assumption of a clear loss waterfall, whether market participants expect small losses or whether they expect large losses but believe that other senior debt still profits from a TBTF subsidy.[3] In this situation, however, only the second interpretation would be a concern for policymakers.

We find that the risk-neutral probability of losses exceeding TLAC primarily depends on the spread difference between bail-in debt and other senior debt, the so-called bail-in risk premium, and on the available amount of eligible bail-in debt. US G-SIBs have more eligible bail-in debt outstanding than their European peers but at the same time the bail-in risk premium is relatively low for US bank holding companies. European banks, especially the ones that issue senior non-preferred debt, have less eligible bail-in debt outstanding but their risk premium is high compared to US G-SIBs. Due to this more pronounced bail-in risk premium, we find that the risk-neutral probability of losses exceeding TLAC is actually lower for European G-SIBs than for US G-SIBs.

As our methodology is based on market prices, the estimated loss distribution reflects market participants' views and expectations. Due to investors' risk-aversion, it may well be that these risk-neutral loss estimates are larger than the losses that regulators have to expect in an actual resolution of a G-SIB. In an empirical study, Conlon and Cotter (2014) find that for most EU banks,

[1] In the context of our model, a gone-concern situation is defined as a stress situation where Tier 2 capital or subordinated debt instruments are subject to losses.

[2] Note that the TLAC standard does not limit the powers that authorities may have to bail-in any debt instrument. Therefore, the expectation that an instrument that is not eligible for TLAC may still be subject to losses is compatible with the TLAC standard.

[3] In this case, public sector support would be similar to an intermediate loss layer, which ranks between bail-in debt and other senior debt.

a bail-in of a relatively small fraction of senior debt would have been sufficient to cover the loan losses in the global financial crisis. As this empirical study does not take into account public sector support, which stabilised the financial system during this crisis, it may underestimate the loss absorbing capacity that is required to resolve a bank without such support.

We do not attempt to decompose the spread of banks' debt instruments into real-world loss expectations and other spread components that may be related to investors' risk aversion or liquidity preferences. Such a decomposition would be strongly dependent on assumptions, as the empirical data on bank losses in resolution is scarce and often distorted by public sector support measures. In particular, the new resolution framework and the bail-in tool remain untested for the complex international business model of G-SIBs.

Despite very different liquidity aspects, we find similar loss expectations both in the credit default swap (CDS) and in the bond market. Due to higher standardisation and different funding aspects, the CDS market is generally more liquid than the underlying bond market. A CDS contract refers to an entire debt category of the reference entity, which makes it less dependent on the specific terms and conditions of a single bond. As a result of these differences, the CDS spreads in our data are significantly lower than the bond spreads. Despite these different liquidity aspects and the different spread levels, we observe a similar relative pricing of different debt categories, which leads to similar loss expectations in our model.

As a further robustness check, we show that our estimates of the risk-neutral expected loss do not depend on the amount of stress in the financial markets. We find that during the market turbulence caused by the Covid-19 pandemic in March 2020, only the parameter for the probability of a gone-concern situation increased in our model. The parameter for the expected loss given a gone-concern situation remained roughly constant. In other words, the sharp increase of credit spreads, which was observed during this market turbulence, can be reproduced with one overall scaling factor for a given issuer. In our model, a simple scaling of all spreads of a given issuer leaves the risk-neutral expectations about how losses will be shared between the different debt categories unchanged.

This finding shows that the substantial expected losses that we measure based on our proposed methodology are not just artefacts of debt pricing during normal periods. During stress periods as well, market participants do not clearly distinguish between bail-in debt and other senior debt, which ranks higher in the banks' creditor hierarchy. Therefore, it would be imprudent to assume that in a resolution market participants would suddenly be assured that only bail-in debt could suffer losses and that other senior debt instruments, which rank pari passu with operational liabilities, would continue to perform.

Market participants' expectations are very relevant for measuring the success of TBTF reforms. Even the most elaborate resolution plans and bail-in powers will not end the TBTF issue if they are not credible in the eyes of market participants. Only if investors are convinced that bail-in debt can be subject to losses in a gone-concern situation, will they exert market discipline and remove the TBTF subsidy. However, market participants do not only have to be convinced that bail-in debt can be subject to losses. They must also be confident that the operating liabilities of the bank, which rank pari passu with other senior debt instruments of the operating bank, will continue to perform, even during a hectic resolution phase. For example, if counterparties cannot be convinced to stay in derivatives contracts or to roll the banks short-term liabilities, this can lead to a further destabilisation of the bank and to a disruption of resolution plans. The resulting losses may be much higher than under an orderly resolution, such that the high losses, which are implied by the relative pricing of bank debt, may become, to some extent, self-fulfilling.

Our study contributes to a large, international effort of evaluating whether the objectives of the TBTF reform have been met. In a recent evaluation report (Financial Stability Board, 2021), the FSB finds that TBTF reforms have reduced market-based measures of systemic risk but that there are still gaps that need to be closed. Investor and analysts, for instance, report a lack of information about the resolvability of G-SIBs that is limiting their ability to assess and price the risks of bail-in debt. Credibility of the TBTF reforms among market participants takes a central place in the FSB evaluation report, because only a credible bail-in framework can eliminate unjustified funding cost advantages and enforce market discipline.

Other approaches for measuring the credibility of bail-in debt also look at the pricing of bail-in debt relative to other debt instruments. The FSB report finds that the credit spread of a bail-in bond is generally higher than the credit spread of a comparable bond from the same issuer that is not eligible for TLAC. Researchers and analysts have emphasised, however, that this bail-in risk premium is relatively small. Afonso et al. (2018) point out that for US G-SIBs the spread difference between bank holding companies and bank subsidiaries remained quite narrow, even after the TBTF reforms. For European G-SIBs, the bail-in risk premium is more pronounced, but a strong demand for the new bail-in debt category also led to a relatively small spread difference between senior preferred and non-preferred debt (Höpker et al., 2017; Nolan, 2018). Lewrick et al. (2019) finds that the bail-in risk premium depends on the issuer and on the marketwide level of credit risk.

The existence of a bail-in risk premium is a necessary condition for a credible TBTF reform. If there were no measurable bail-in risk premium, market participants would have serious doubts about the effectiveness of the bail-in tool. The mere existence of a bail-in risk premium, however, is insufficient evidence that the TBTF reforms have achieved their objectives. Our study makes a novel contribution to the evaluation effort of the TBTF reforms by proposing a way to determine whether the observed bail-in risk premium is sufficiently high to be in line with the objectives of the TBTF reforms.

This paper is organized as follows. We highlight the related literature in section 2 and provide some additional background on the new TLAC standard and its implementation in different jurisdictions in section 3. Section 4 introduces our model and discusses its different parametrisations. It also illustrates how the credit spreads of a G-SIB should evolve according to our model, as the bank builds up its bail-in debt capacity. Section 5 provides information on our sample, on the bond and CDS market data, and on the estimation approach. Section 6 presents the results and discusses our estimates of the model parameters. In section 7, we discuss the relevance of these results from a regulatory perspective and argue that the distinction between bail-in debt and other liabilities should be improved. We summarise and conclude in section 8.

2 Related Literature

There are different strategies to analyse the credibility of a bail-in for G-SIBs based on market data. One strategy is to compare the credit spreads of G-SIBs to credit spreads of smaller banks or non-financial firms. Based on this strategy Acharya et al. (2016), for example, find a TBTF subsidy for the largest financial institutions, which is not seen in non-financial sectors.

Another strategy is to compare the observed credit spreads of G-SIBs to the equity-implied credit spreads or default probabilities. Conceptually, this strategy is based on the classic Merton model (Merton, 1974), which has been refined and developed in different ways. Moody's has developed the CreditEdge model, which calculates fair-value CDS spreads based on equity market data. Building on this model, Jobst and Gray (2013) propose a systemic contingent claims analysis to estimate TBTF subsidies of the financial sector during times of stress. Based on a similar approach, Allenspach et al. (2020) find that large banks still benefit from a TBTF subsidy. Gudmundsson (2016) use a jump diffusion option-pricing approach to estimate implicit government subsidies for banks. Berndt et al. (2019) propose a methodology to estimate bail-out probabilities based on equity and spread data. Comparing pre- and post-crisis market data for US banks, they find that the market-implied probabilities of government bailouts have been reduced. Several studies also compare the pricing of contingent-convertible debt (CoCos) to equity and bail-in debt. Event studies (Fiordelisi et al., 2020; Hau and Hrasko, 2018) show that, depending on the design features, market participants consider CoCos as going-concern or gone-concern capital. The FSB evaluation report (Financial Stability Board, 2021) provides a detailed review on the credibility of the TBTF reforms and the related literature.

Our paper also compares the pricing of different bank liabilities with option-pricing methods, but in contrast to the studies above, it focuses entirely on gone-concern debt instruments. Rather than estimating the value of government subsidies or the probability of bailouts, we estimate the market-implied losses conditional on a gone-concern situation. For estimating such tail events in a firms' asset distribution, gone-concern debt instruments should contain the most relevant information. In this sense, our paper is similar to the recent paper of Aramonte et al. (2021), which proposes to estimate the skew in the risk-neutral equity returns distribution based on CDS data.

In terms of data, this paper is closely related to several empirical studies that analyse the bail-in risk premium, i.e., the spread difference between bail-in debt and other senior bank debt. Lewrick et al. (2019) finds that this premium is higher for riskier issuers, consistent with the notion of market discipline. In the same vein, Lindstrom and Osborne (2020) find that the risk sensitivity of European banks' credit spreads has increased since the regulatory reforms. Gimber and Rajan (2019) highlight that, under the assumption of a credible bail-in, the spreads of senior unsecured debt should decrease as there are more junior sources in the creditor hierarchy. They find that, ceteris paribus, banks with more subordinated and less senior unsecured debt have lower risk premia on senior unsecured debt. They also find that when banks have more equity and less subordinated debt they have lower risk premia on both. Pablos Nuevo (2019) investigates the impact of the EU bail-in framework on the spread difference between subordinated and senior unsecured bonds. Her results show a convergence for G-SIBs and non-G-SIBs after the introduction of the new bail-in framework. Her results also point out the relevance of the Tier 1 capital ratio for the pricing of subordinated debt. We add a structural interpretation to these papers by studying whether the observed bail-in risk premium is *high enough* to be consistent with the bail-in framework.

In terms of policy implications, this paper reinforces the findings of several studies that call for more clarity and less regulatory discretion in banks' bail-in and resolution frameworks. Tröger (2019) criticizes the European resolution framework as highly complex and with too much discretion for supervisors and resolution authorities. Hwang (2017) finds theoretically and empirically that a bail-in is less likely when the trigger is discretionary. Huertas (2019) points out the importance for investors to have more clarity about the entire resolution process in order to adequately assess the risks involved in bail-in debt. Similarly, the FSB evaluation report of the TBTF reforms (Financial Stability Board, 2021) suggests opportunities to enhance the credibility of reforms by providing more information relating to the operation of resolution frameworks.

3 Regulatory Background

The principles and terms of the new international minimum standard on TLAC are established in a Term Sheet that the FSB adopted in 2015 (Financial Stability Board, 2015). The purpose of this minimum standard is to ensure sufficient loss-absorbing capacity to implement an orderly resolution and to avoid exposing public funds to loss with a high degree of confidence.

The FSB sets both a risk-weighted and a leverage ratio TLAC requirement. Since 1 January 2019, the minimum TLAC for advanced economy G-SIBs must amount to 16% of risk-weighted assets (RWA) and to 6% of the Basel III leverage ratio exposure (LRE).[4] Note that this calibration corresponds to a doubling of the Basel III minimum capital requirements of 8% and 3%, respectively. Conceptually, the amount of bail-in debt has therefore been calibrated to provide a *reserve tank of capital*. As of 1 January 2022, the minimum TLAC requirement will increase to at least 18% of RWA and 6.75% of LRE. If a G-SIB meets all its Basel III capital requirements, it must build-up a bail-in debt capacity amounting to the larger of 10% RWA and 3.75% LRE in order to meet this TLAC requirement.[5]

For most G-SIBs and all the G-SIBs analysed in this paper, the preferred resolution strategy is a single point-of-entry (SPE) strategy. This means that they have a single resolution entity that issues all external TLAC. To ensure the appropriate distribution of loss-absorbing and recapitalisation

[4] The corresponding Basel III capital buffers must be met in addition to the TLAC minimum requirements.

[5] A G-SIB may use additional regulatory capital instruments to meet the TLAC requirement but there is the expectation that at least one third of the minimum TLAC requirement is met with debt instruments to help ensure that there is sufficient outstanding long-term debt for absorbing losses in resolution.

capacity within the resolution group, the standard also defines internal TLAC requirements for material subgroups.

For a debt instrument to be eligible for TLAC it must be fully paid-in, unsecured, issued by the resolution entity, and have a remaining maturity of at least one year. Deposits, structured notes, liabilities arising from derivatives or any liabilities that cannot be bailed-in without material legal risk are excluded from TLAC (excluded liabilities).

The most relevant eligibility criterion in the context of this paper is that TLAC generally must absorb losses prior to such excluded liabilities of the resolution entity in insolvency or in resolution. To meet this subordination criterion, TLAC must be either contractually subordinated to excluded liabilities of the resolution entity (contractual subordination), be junior in the statutory creditor hierarchy than excluded liabilities of the resolution entity (statutory subordination), or be issued by a resolution entity that does not have more than 5% of excluded liabilities on its balance sheet (structural subordination).

In the US, the UK, and in Switzerland, banks make use of their legal entity structures and meet their TLAC requirements by issuing senior unsecured debt out of their holding companies (HoldCo), which is structurally subordinated to senior unsecured debt of their operating bank entities (OpCo). In France, Germany, and other European jurisdictions, a new debt category of senior non-preferred debt has been created, which ranks between subordinated and other (preferred) senior debt.[6] This new type of senior non-preferred debt will be eligible for TLAC as it will absorb losses prior to preferred senior debt and excluded liabilities. Figure 1 provides a simplified overview on the different subordination approaches and the corresponding "waterfall" in the creditor hierarchy. A detailed discussion of the different resolution regimes in Europe and in the US can be found in Philippon and Salord (2017).

4 Theoretical Model

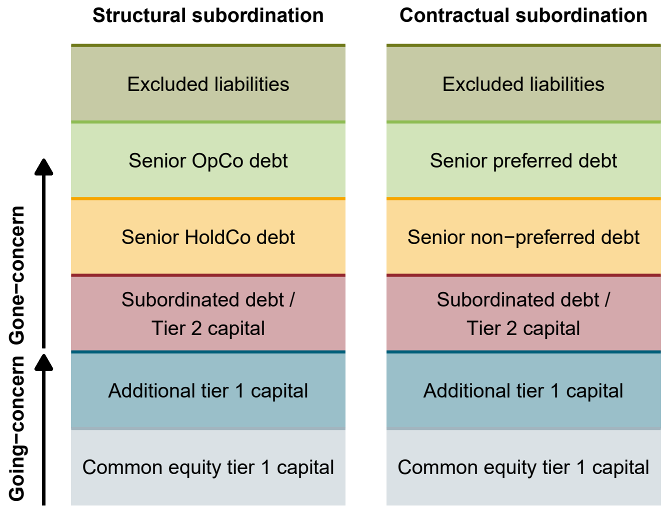
In this section, we propose a structural debt model that allows us to extract information about the tail of a bank's risk-neutral loss distribution based on the market prices of different debt instruments.

4.1 Risk-neutral pricing of debt layers

In option-pricing theory, we can determine the price of any option that matures at time T if we know the risk-neutral distribution of the underlying asset at time T. Conversely, if we know the prices of a complete set of options that matures at time T, we can construct the implied risk-neutral distribution that is consistent with the observed option prices.

[6]France only counts debt that has been issued with a specific contractual clause as senior non-preferred debt. Germany has initially pursued a purely statutory subordination approach and made certain senior unsecured bonds eligible for TLAC by a change in German law. Since 2018, however, German banks also have to declare new bond issues as senior non-preferred in order to be eligible for TLAC. The new senior non-preferred bonds will rank alongside the still outstanding legacy senior bonds.

Figure 1: Overview on different subordination types



Note: Structural subordination is the subordination method applied by US, UK, and Swiss G-SIBs. Contractual subordination is the subordination method applied by most G-SIBs in the EU.

In the classical Merton model (Merton, 1974), this option pricing approach is applied to a simple liability structure, consisting of equity and one single debt layer. Black and Cox (1976) generalised this model to price junior and senior debt layers separately. In the practical application of these models, the risk-neutral asset distributions is often calibrated based the firm's equity market prices.

The amount of information that can be extracted from equity prices about the tail of the loss distribution is limited, as the pay-off function of equity is identically zero as soon as any debt instrument suffers a loss. However, if a firm has many different debt layers with different seniorities, which are all maturing at time T, it should be possible to infer from these debt prices more information about the tail of the loss distribution.

In order to apply and formalise this idea, we consider a firm with total amount of debt D, which consists of n debt layers with notional amount N_i. The layers are ordered by increasing seniority and we denote the upper and lower boundaries of layer i by L_i^+ and L_i^-, respectively. The following two relations summarise our notation for the debt layers:

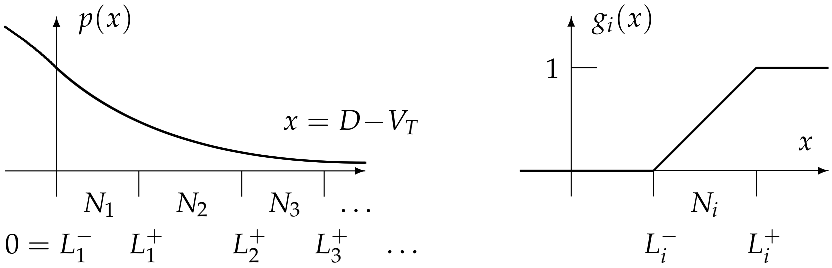
$$0 = L_1^- < L_1^+ = L_2^- \cdots < L_n^+ = D \tag{1}$$

and

$$N_i = L_i^+ - L_i^- \text{ for } i = 1 \dots n. \tag{2}$$

For simplicity, we assume that all debt instruments of the firm are zero-coupon bonds without any covenants or option features and with a remaining time to maturity of T years. The only difference between the debt instruments in the different layers is their ranking as claimants on the firm's

Figure 2: The probability density function $p(x)$ and the loss function $g_i(x)$



Note: The lhs illustrates the risk-neutral probability density function $p(x)$ for the random variable $x = D - V_T$. The valuation of debt layers $N_1, \ldots, N_n$ depends only on the tail of this function, i.e., on the values for $x > 0$. The rhs shows the loss function $g_i(x)$, which determines the loss per unit of notional amount for an instrument in the debt layer i. Note that the payoff per unit of notional amount is given by $1 - g_i(x)$.

assets.

Furthermore, we denote the value of the firm's assets at time T by the variable V_T and define the variable $x_T = D - V_T$. If x_T is positive, it measures the loss that must be absorbed by debt instruments at time T. As our model considers only a single time period, we will drop the index T in the following. The variable x is a random variable and we denote the risk-neutral probability density function of x by $p(x)$, where x can take any value in the range $(-\infty, \infty)$.[7]

We can describe the payoff of the debt layer i at time T as a function of the variable x. If $x < L_i^-$, the zero-coupon bonds in debt layer i will pay their full notional amount, N_i. If $x > L_i^-$, these bonds will only pay a fraction of the notional amount, and if $x > L_i^+$, they will pay nothing. The pay-off function of the debt layer i is given by the formula

$$f_i(x) = N_i(1 - g_i(x)), \tag{3}$$

where $g_i(x)$ is the loss function for debt layer i and is defined as

$$g_i(x) = \min(1, \max((x - L_i^-)/N_i, 0)). \tag{4}$$

The probability density function $p(x)$ and the loss function $g_i(x)$ are illustrated in Figure 2.

In risk-neutral pricing theory, the arbitrage-free price of any financial claim is given by its expected payoff under the risk-neutral probability measure, discounted at the risk-free interest rate. Having introduced the risk-neutral probability density function of the random variable x and the

[7] As the firm's assets at time T can take any positive value and as we assume total debt to be constant, $x = D - V_T$ can take any value in the range $(-\infty, D)$. As it is very unlikely that the assets of a bank lose all their value, the probability density function is actually concentrated on a much narrower range. We will only apply our model to debt layers up to approximately 10% of total debt D. For the pricing of these debt layers, only the total probability that losses exceed these debt layers but not the actual distribution of these losses is relevant (c.f. Eq. (6)). Therefore it is not necessary to require that our parametric descriptions of $p(x)$ is strictly zero for $x > D$.

pay-off functions of the debt layers, we can express the present value of debt layer i as

$$v_i = e^{-rT} \int f_i(x) p(x) \mathrm{d}x = e^{-rT} N_i \left(1 - \int_{L_i^-}^{\infty} g_i(x) p(x) \mathrm{d}x \right), \tag{5}$$

where r denotes the risk-free interest rate. In the second equation, we have used the definition in Eq. (3) and the fact that the loss function $g_i(x)$ is zero for $x < L_i^-$. The integral in the second equation is the expected loss per notional amount of layer i under the risk-neutral probability measure with density function $p(x)$. We denote this expected loss as

$$l_i := \int_{L_i^-}^{\infty} g_i(x) p(x) \, \mathrm{d}x = \frac{1}{N_i} \int_{L_i^-}^{L_i^+} (x - L_i^-) p(x) \, \mathrm{d}x + \int_{L_i^+}^{\infty} p(x) \, \mathrm{d}x, \tag{6}$$

where we have used in the second equation the definition of the loss function in Eq. (4).

The present value v_i can be translated into a spread over the risk-free rate s_i with the definition $v_i = N_i e^{-(r+s_i)T}$. From Eq. (5) and with the definition in Eq. (6), we obtain

$$s_i = -\frac{\ln(1 - l_i)}{T} \quad \text{or} \quad l_i = 1 - e^{-s_i T}. \tag{7}$$

If the expected loss under the risk-neutral measure for debt layer i is small, i.e., if $l_i \ll 1$, the spread is approximately given by l_i divided by the number of years to maturity,

$$s_i \approx \frac{l_i}{T}. \tag{8}$$

The risk-neutral pricing method satisfies the Modigliani Miller theorem. The expected losses can be distributed over different layers but the total present value of these expected losses always remains the same. If we have a debt layer $[A, C]$ with attachment point A and detachment point C and we split it into a non-preferred debt layer $[A, B]$ and a preferred layer $[B, C]$, it is straightforward to show from Eq. (5) that the following formulation of the Modigliani Miller theorem holds:

$$v_{[A,C]} = v_{[A,B]} + v_{[B,C]}. \tag{9}$$

4.2 Choosing a parametrisation

The risk-neutral probability density $p(x)$ introduced in section 4.1 is not directly observable for market participants. Therefore, we assume a parametric description of the risk-neutral probability density $p(x)$ and we determine the parameters based on observable market prices. The most common parametric description for the density function $p(x)$ is the log-normal density function. If we denote the implied asset volatility by σ and the current market value of the assets by V_0, we can write the risk-neutral density function of the Merton model in our notation as

$$p_{\text{Merton}}(x) = \frac{1}{\sqrt{2\pi\sigma^2 T}(D-x)} \exp\left(-\frac{\left[\ln\left(\frac{D-x}{V_0}\right) + \left(r - \frac{\sigma^2}{2}\right) T\right]^2}{2\sigma^2 T} \right).^{8} \tag{10}$$

The log-normal distribution has the advantage that it allows the firm's equity and debt instruments to be priced with the standard Black and Scholes formulas. A log-normal asset distribution may work reasonably well for non-financial firms, but Nagel and Purnanandam (2019) show that this choice overestimates the upside and underestimates the downside potential in banks' asset dynamics.

In this study, we will introduce and work with new parametrisations of the density function $p(x)$ that are more suited for our purposes than the log-normal density of the Merton model. As we will work only with debt and not with equity instruments, we do not need to know the entire distribution but only the tail of the distribution that corresponds to a default of the firm. In fact, from Eq. (5) we see that the valuation of debt instruments in layer i does not depend on $p(x)$ for values of x smaller than $L_i^- \geq 0$. Therefore, we need to parametrise the function $p(x)$ only for $x > 0$ and we will still be able to price all debt layers of the firm.

The log-normal distribution is not a natural choice for parametrising the tail of a distribution. The two parameters of the Merton model (current asset value and asset volatility) describe the head of the distribution as they are related to the first two moments of the entire distribution. If we are only interested in the tail of the distribution, it is more natural to work with lower partial moments. We define the parameters α and λ as the first two lower partial moments of the probability density function $p(x)$,

$$\alpha = \int_0^\infty p(x)\,\mathrm{d}x \quad \text{and} \quad \lambda = \frac{1}{\alpha}\int_0^\infty x\,p(x)\,\mathrm{d}x. \tag{11}$$

The dimensionless parameter α is the probability of a gone-concern situation at time T and the parameter λ is the expected loss given a gone-concern situation at time T.

A natural parametrisation for tail of $p(x)$ that has the two partial moments as described in Eq. (11) is the following exponential density function

$$p_{\exp}(x) = \frac{\alpha}{\lambda} e^{-x/\lambda} \quad \text{for} \quad x > 0. \tag{12}$$

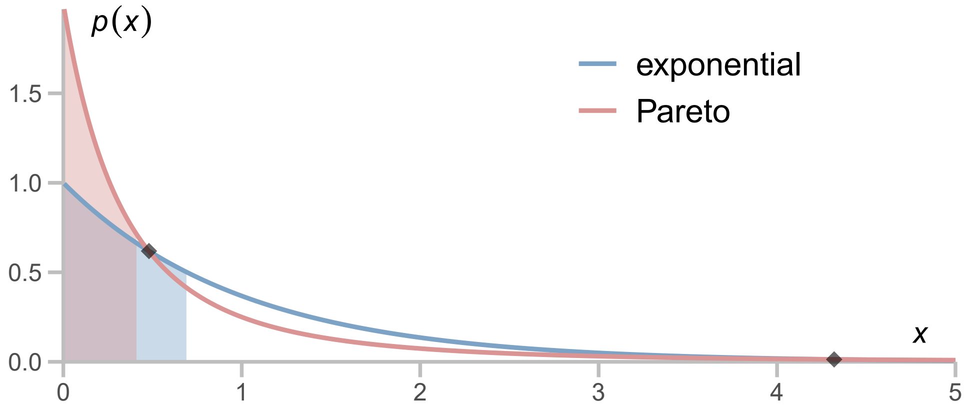
Inserting this function into Eq. (6) and evaluating the integrals, we obtain the following expression for the expected loss of layer i

$$l_{\exp,i} = \alpha e^{-L_i^-/\lambda} \, \frac{1 - e^{-N_i/\lambda}}{N_i/\lambda}. \tag{13}$$

Note that the expected loss of layer i in Eq. (13) is the product of the probability of default of layer i, given by the first term $\alpha e^{-L_i^-/\lambda}$, and the loss given default of layer i, given by the second term. The loss given default of layer i is approximately 1 for $N_i \ll \lambda$ and goes to zero as λ/N_i for $N_i \gg \lambda$.

[8] Note that p_{Merton} is only defined for $x < D$ but we could extend it to all x by setting it to zero for $x > D$.

Figure 3: Comparison of the exponential and the Pareto loss distribution



Note: Comparison of the exponential and the Pareto loss distribution function with $\lambda = 1$. The Pareto density is heavier for small values and in the tail but is lighter in the head of the distribution (indicated by the black markers). The median of the exponential distribution is $\ln 2 \approx 0.69$ and the median of the Pareto distribution is $\sqrt{2} - 1 \approx 0.41$ (indicated by the shaded areas).

The exponential probability density function, as defined in Eq. (12), is not the only possible parametrisation with partial moments as described in Eq. (11). For example, the density distribution could have more weight in the tail and around zero and less weight in the head of the distribution. An example of such a distribution is the following Pareto distribution[9]

$$p_{\text{Pareto}}(x) = \frac{2\alpha\lambda^2}{(x+\lambda)^3} \quad \text{for} \quad x > 0, \tag{14}$$

which is compared graphically to the exponential function in Figure 3. Inserting this density into Eq. (6) and evaluating the integrals, we obtain the following expression for the expected loss of layer i

$$l_{\text{Pareto},i} = \frac{\alpha\lambda^2}{(L_i^- + \lambda)^2} \frac{L_i^- + \lambda}{L_i^+ + \lambda}, \tag{15}$$

where we have arranged the terms such that the first factor corresponds to the probability of default of layer i and the second term to the loss given default. In this study, we will work with these two parametrisations and we will assess how our results depend on the choice.

Besides the expected loss parameter, λ, we are also interested in the conditional probability that a loss exceeds the total loss-absorbing capacity, given a gone-concern situation. We will denote this probability as π_{TLAC} or simply as π. More generally, we can define the probability π_i as the probability that the losses exceed the debt layer i in a gone-concern situation. Note that in our notation, the bank is in a gone-concern situation when the losses reach the debt layers, i.e., if the random variable x is greater than 0. We can calculate this probability as

$$\pi_i = \frac{1}{\alpha} \int_{L_i^+}^{\infty} p(x) \mathrm{d}x. \tag{16}$$

[9]This is the Pareto distribution with scale parameter λ and shape parameter equal to 2.

4.3 A stylized example

For a stylized illustration of our model, we first calibrate the model parameters based on typical values of senior and subordinated credit spreads and typical values of the corresponding debt layers and then predict with our model what happens as a G-SIB builds up the required mezzanine layer of bail-in debt.

We assume that the total amount of long-term unsecured debt that the G-SIB has issued amounts to 7% (or 10%) of LRE and that this amount remains constant. At the beginning, before the G-SIB starts to issue bail-in debt, this total amount consists only of senior unsecured debt which is not eligible for TLAC and subordinated debt. The amount of subordinated debt remains also constant at 0.75% of LRE. We assume further that at the beginning, the G-SIB's credit spread for subordinated debt with a maturity of five years amounts to 200bps and the credit spread for senior unsecured debt with the same maturity amounts to 50bps.

With the formula in Eq. (7), we first translate the two credit spreads into the expected losses $l_i = 1 - e^{-s_i T}$, where the index i refers to subordinated or senior unsecured debt. Then, we can determine the two parameters α and λ by solving the two equations $l_i = l_{\text{exp},i}$, where $l_{\text{exp},i}$ is defined as in Eq. (13). For the Pareto distribution, we solve the equations $l_i = l_{\text{Pareto},i}$, where $l_{\text{Pareto},i}$ is defined as in Eq. (15). The results are shown in Table 1 for both the exponential and the Pareto loss distribution.

Table 1: The model parameters in the stylized example

Model	**7% debt**			**10% debt**		
	α	λ	$\tilde{\lambda}$	α	λ	$\tilde{\lambda}$
exponential	11.4%	2.1%	1.4%	10.8%	2.9%	2.0%
Pareto	12.4%	2.5%	1.0%	11.6%	3.5%	1.5%

Note: This table shows the model parameters that have been obtained in the stylized example for the exponential and the Pareto loss distribution. The parameters have been fitted assuming both 7% and 10% of total long-term debt. The parameters for 7% of debt corresponds to the example shown in Figure 4. λ denotes the expected and $\tilde{\lambda}$ the median loss. These loss parameters and the amount of debt are measured in units of LRE.

The parameter α, which provides the probability of a gone-concern situation, does not depend much on the model or the thickness of the debt layer. Given that the subordinated debt layer is relatively thin, α is mainly determined by the spread of the subordinated debt instrument (200bps). As we have assumed a maturity of five years, this amounts to a cumulative probability of a gone-concern situation of approximately 10%.

The expected loss parameter λ does depend on the thickness of the total debt layer. If the amount of senior unsecured debt is increased, the expected loss parameter λ in our model has to increase as well in order to reproduce the assumed senior credit spread of 50bps. For the Pareto model, the λ is larger than for the exponential model because the Pareto distribution has a heavy tail. The median loss, which we denote by $\tilde{\lambda}$ in Table 1, is, however, smaller in the Pareto model compared to the exponential model.

We now assume that the G-SIB starts to replace senior unsecured debt with bail-in debt, which ranks between subordinated and senior debt, keeping the estimated parameters of the loss distribution constant. As our model is consistent with the Modigliani Miller theorem, the credit spreads that correspond to the different debt layers will change but the total value of the debt layers will remain constant (cf. Eq. (9)). Figure 4 illustrates the case where the G-SIB has issued in total 7% of its LRE in the form of unsecured long-term debt.

We discuss the dependence of the credit spreads and the probability of losses exceeding TLAC by looking at three different levels of TLAC. The three levels of TLAC correspond to the first issuance of bail-in debt (0.75% of loss-absorbing debt), the level where the bank reaches the FSB requirement (3.75% of loss-absorbing debt), and the point where the bank has replaced all the original senior debt with bail-in debt (7% of loss-absorbing debt). These three points are also shown in Table 2 and are highlighted in Figure 4 by vertical grid lines.

Table 2: Credit spreads and the probability of a loss greater than TLAC in the stylized example

	exponential			**Pareto**		
Loss-absorbing debt (% LRE)	0.75	3.75	7.00	0.75	3.75	7.00
Spread bail-in debt (bps)	164	85	50	151	77	50
Spread senior unsecured (bps)	50	18	8	50	26	17
Prob. loss greater TLAC (%)	69	16	3	59	16	7

Note: This table shows the bond spreads and the probability of a loss greater than TLAC, conditional on a gone-concern situation, for the example shown in Figure 4. This example assumes 7% of total long-term debt. The values are shown for three different levels of loss-absorbing debt and for both the exponential and the Pareto loss distribution.

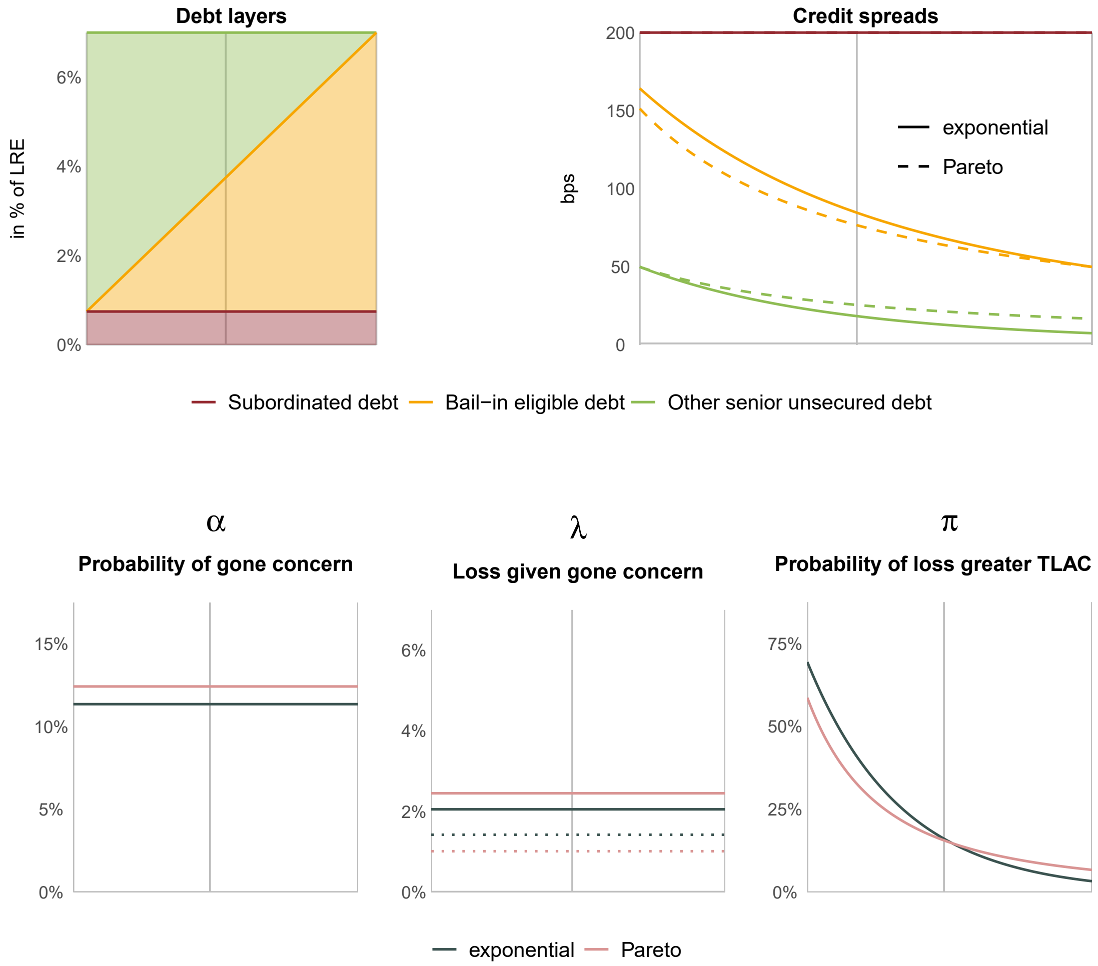
The credit spread the bank must pay for bail-in debt at its first issuance is relatively high (164bps for the exponential model) but decreases quite rapidly. The reason for this decrease is that the expected loss given default for this layer decreases (cf. Eqs. 13 and 15). At the point where the bank meets the FSB requirement, the spread has reduced to 85bps in the exponential model and it reaches 50bps at the point where the original debt has been fully replaced.

The credit spread for senior debt also decreases as the bank is building up a lower-ranking layer of loss-absorbing debt. Starting from its original value of 50bps it reaches 18bps at the point where the bank meets the regulatory requirement and goes down to only 8bps once the bank has issued 7% of loss-absorbing debt.

The overall dependence of the spreads in the Pareto distribution is similar to the exponential distribution. Note, however, that the spread difference between senior unsecured debt and bail-in debt is smaller in the Pareto distribution, due to its heavy tail.

As expected and as intended by policymakers, the probability of losses exceeding TLAC in a gone-concern situation decreases as the bank is building up bail-in debt. At the beginning, the probability is quite high as the subordinated debt layer is relatively thin. Once the bank has reached the regulatory TLAC requirement, this probability has decreased to approximately 16% in both

Figure 4: Time development of layers, spreads, and probabilities in the stylized example



Note: The upper left panel shows how the bank constantly builds up bail-in debt by replacing other senior unsecured debt. The upper right panel shows how this affects the corresponding credit spreads. The left two bottom panels show the model parameters α (probability of a gone-concern within five years) and λ (expected loss given a gone-concern situation), which have been calibrated to reproduce the assumed 50bps senior and 200bps subordinated issuer spreads before the issuance of bail-in debt and which are kept constant. The bottom right panel shows the time development of the conditional probability of losses exceeding TLAC, π. The vertical grid line in all panels corresponds to the time where the bank has issued 3% of bail-in debt and hence meets the regulatory TLAC requirement. Both the loss parameters and the debt layers are measured in units of LRE. The dotted lines in the lower middle panel show the median loss.

models and continues to decrease as the bank is issuing more bail-in debt. Note that due to its heavy tail, this probability decreases more slowly in the Pareto distribution.

5 Data and Methodology

Our sample consists of eleven G-SIBs that we split by region and issuance model for bail-in debt into three different groups as shown in Table 3. The European G-SIBs issue bail-in debt as senior unsecured debt out of their holding company (HoldCo) or as senior non-preferred debt out of their operating company (OpCo). The US G-SIBs issue bail-in debt as senior HoldCo debt.

Table 3: The sample of G-SIBs considered in this study

G-SIB	Symbol	Country	Issuance	Bond
Credit Suisse	CS	CH	HoldCo	x
UBS	UBS	CH	HoldCo	x
Barclays	Barclays	UK	HoldCo	x
ING Bank	ING	NL	HoldCo	x
Groupe Crédit Agricole	CredAgr	FR	OpCo	
BNP Paribas	BNP	FR	OpCo	x
Société Générale	SocGen	FR	OpCo	x
Deutsche Bank	DB	DE	OpCo	x
Bank of America	BoA	US	HoldCo	
JP Morgan Chase	JPM	US	HoldCo	
Wells Fargo	WF	US	HoldCo	x

Note: This table shows the sample of G-SIBs considered in this study together with the symbol used to abbreviate the bank names in charts and tables. The sample is grouped into three subsamples according to banks' region and issuance model for bail-in debt. The sample for the bond spread analysis is smaller as indicated by the last column.

We consider both CDS spreads and bond spreads as market variables for credit spreads. Working with CDS spreads has the advantage that standardised contracts for the three different types of debt instruments are available for all G-SIBs in Table 3. We base our analysis on the CDS contracts with a tenor of five years, as these contracts are the most standard contracts and because five years is a typical tenor for bail-in debt. For the European G-SIBs that issue bail-in debt out of their operating bank company, we use the CDS contracts that refer to subordinated, senior non-preferred, and senior preferred debt. For G-SIBs that issue bail-in debt out of their holding company, we use the CDS contracts that refer to subordinated debt, senior unsecured HoldCo debt, and senior unsecured OpCo debt. All CDS data are obtained from Markit. More detailed information on the CDS tickers that we use for each G-SIB can be found in Table A.2 in the Appendix A.1.

Working with bond spreads is more difficult, as, for each G-SIB, we have to find liquid bonds with standard terms for all three seniorities (subordinated, senior non-preferred / HoldCo, senior preferred / OpCo). Furthermore, the bonds should have similar maturities of approximately five years. Due to these restrictions, the sample of G-SIBs for which we could find suitable bond data is somewhat smaller than for CDS data (cf. Table 3). The actual bonds that we have used for each G-SIB can be found in Table A.1 in the Appendix A.1. For these bonds, we obtain the credit spread with respect to a risk-free government benchmark bond from Refinitiv.

Confirming our results with both synthetic (CDS) and cash (bond) market data is an important robustness check. The synthetic market tries to replicate the payoff of the cash market in the case of a gone-concern situation or default.[10] In terms of funding or liquidity, there are significant differences between these two markets. If we find similar results based on either type of market data we can have some confidence that these findings are not driven by specific aspects of the cash or synthetic markets but are driven by the common aspect of these two markets, i.e., market participants expectations about the losses in a gone-concern situation.

We use five quarters of market data from 3Q 2019 to 3Q 2020. We choose to work with a common time frame for all banks in order to facilitate the comparison of bank-specific results.[11] Note that before 3Q 2019, there was not enough good quality CDS data for all banks in the sample. Separate CDS contracts for non-preferred and preferred senior debt have been traded since 2018 for the French G-SIBs and only since 2019 for Deutsche Bank. The time frame of our analysis contains a period of significant market stress due to the global outbreak of the Covid-19 pandemic in March 2020. For our analysis, this has the advantage that we can estimate our parameters both under normal and stressed market conditions.

For the debt layers, we use the disclosed amounts of Tier 2 capital and bail-in debt and normalise these amounts by dividing them by the banks' Basel III LRE. Furthermore, we make the assumption that the total amount of long-term unsecured debt, including subordinated and bail-in debt, amounts to 7% of the LRE for all banks. We use this uniform assumption as there is not a sufficiently standardised and consistent reporting of outstanding long-term debt for all banks in our sample. A uniform assumption for the total amount of long-term debt is reasonable, as banks build up bail-in debt by replacing other long-term unsecured debt, keeping the total amount of long-term unsecured debt more or less constant.

Assuming less than 7% of long-term unsecured debt for all banks would not be possible, as certain US banks in the sample have Tier 2 and bail-in debt outstanding that exceeds 6% of their LRE. For these banks the amount of long-term OpCo debt is relatively small. European banks have started to issue bail-in debt more recently and generally still have less bail-in debt than their US peers. Correspondingly, the amount of senior debt that is not eligible for TLAC is larger for these banks.

It is conceivable to assume a higher amount of long-term unsecured debt, but our results show that this would reinforce our main findings even more. The estimates of the expected loss parameter λ and of the probability of losses exceeding TLAC, π, increase further if we assume higher

[10] In order to better align the payoff of the synthetic market with the cash market and, in particular, to make sure that CDS contracts on banks will pay in the case of a regulatory bail-in, the industry changed the ISDA Credit Derivatives Definitions in 2014, which led to a significant increase in CDS spreads for European banks. Neuberg et al. (2016) propose to use the spread difference between the new and old CDS contract to estimate market-implied bail-in probabilities.

[11] Only for the bond analysis of Société Générale the time frame is shorter as can be seen in Appendix A.6.

amounts of long-term unsecured debt. Therefore, we discuss in this section only the results based on the uniform assumption of 7% long-term debt and provide the results for 10% long-term debt in Appendix A.2.

All the results presented in section 6 are obtained as follows. Based on the credit spreads and debt layers as inputs, we fit the parameters of the risk-neutral loss distribution for each business day and for each bank in the observed time period. To reduce the volatility in the results, we calculate a moving average of the credit spreads over ten business days. As our model has only two parameters (α and λ), we will calibrate these parameters for each business day by minimizing the total square distance between the model-based fit and the actual market spread (See Appendix A.3 for further details).

6 Results

In this section, we will estimate the probability of a gone-concern situation (α), the expected loss given a gone-concern situation (λ), and the probability of losses exceeding TLAC (π) with our model using the actual credit spreads and debt layers of G-SIBs.

6.1 Aggregated results based on CDS

We start the discussion by looking at the CDS results averaged over all G-SIBs in the sample. Figure 5 shows the CDS spreads (grey lines) together with the model-implied CDS spreads (coloured lines) averaged over all banks in the sample.[12] The plot shows that, overall, the model-implied spreads match the actual CDS spreads quite well.

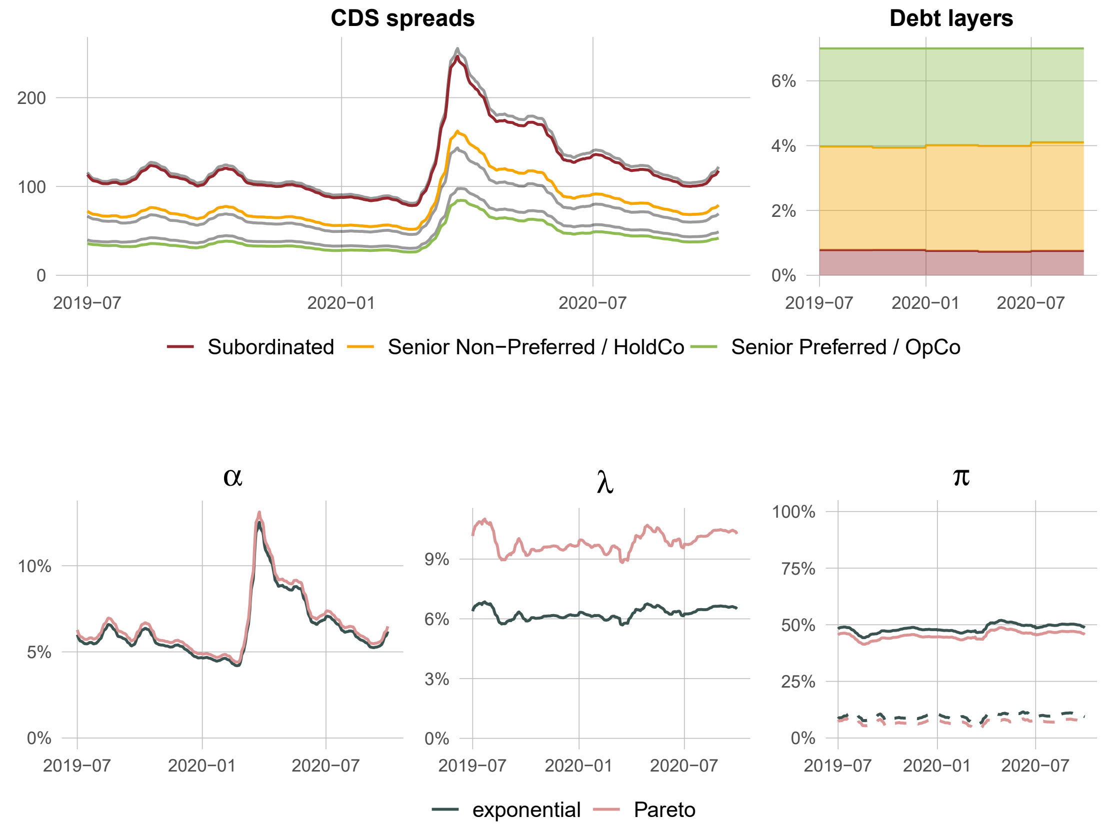
It is worth noting, however, that the model-implied CDS spreads do not match the actual CDS spreads exactly as the bail-in risk premium is relatively small. According to our model the observed spread difference between bail-in debt and other senior debt (the bail-in risk premium) is too small given the large spread difference between bail-in debt and subordinated debt. In Figure 5 we show the fitted spreads assuming an exponentially decaying loss function. If we assume the Pareto loss distribution, which has fat tails, the fitting improves only slightly and the relatively small spread difference between bail-in debt and other debt still cannot be reproduced. The dashed curves in the lower right panel show the fraction of unexplained variance for both the exponential and the Pareto distribution.

The purpose of our method is not to fit all three CDS spreads exactly but to estimate the expected loss given a gone-concern situation from a simple risk-neutral loss distribution. In order to do this, we restrict ourselves to natural and simple parametrisations for the tail of the risk-neutral probability density function. It would of course be possible to fit all three CDS spreads exactly with a sufficiently complex parametrisation of the density function.[13]

[12]Note, that we first calculate the parameters and the fitted CDS for each bank and business day and then average these calculate variables and spreads over all banks in the sample.

[13]The situation here is similar as in standard option pricing theory: The Black Scholes model allows reproducing the price of one vanilla option with a given strike and maturity exactly, if the volatility of the underlying, σ, is fitted

Figure 5: Time development of CDS spreads, layers, and parameters averaged over all banks



Note: The top panel shows the model-implied (colour) and actual (grey) CDS spreads and the corresponding debt layers. The first two bottom panels show the fitted model parameters α (probability of gone concern) and λ (expected loss given gone concern). The last bottom panel shows the measure π (probability of loss exceeding TLAC given gone concern) together with the fraction of unexplained variance (dashed lines). The fitted spreads in the top panel are shown for the exponential loss function. The measures in the bottom panels are shown for both the exponential and the Pareto loss function. The measures in all panels are averaged over all banks in the sample. Debt layers and losses are measured in % of LRE.

Our calculations show that during a stress period, the risk-neutral probability of a gone-concern situation increases while the expected loss given a gone-concern situation remains fairly constant. In Figure 5, the parameter α increases sharply in March 2020 during the Covid-19 market turbulence. The parameter λ, which measure the expected loss given a gone-concern situation, does not show such a clear peak in March 2020 and remains fairly constant during the entire observation period. This result is quite important for us because it shows that the expected losses that we estimate during normal periods are also relevant for periods of stress. If the parameter λ would depend strongly on the overall stress level, the relevance of our findings for gone-concern situations,

correctly. With a constant σ, however, the Black Scholes model does not always produce the correct prices for options with different strikes. The reason for this is that the restriction to a log-normal risk-neutral distribution of the underlying is not flexible enough. It is, however, always possible to reproduce all arbitrage-free options prices for a given maturity and a given underlying exactly by choosing a sufficiently complex risk-neutral distribution of the underlying at maturity.

which are situations of very high stress, could be questioned.

Figure 5 also shows that the expected loss given a gone-concern situation is quite high and exceeds the available loss-absorbing capacity. In the sample average, the estimated risk-neutral parameter λ is approximately 6% of LRE for the exponential model and is even higher for the Pareto model. This risk-neutral loss estimate is clearly higher than the loss-absorbing capacity of approximately 4% in the averaged sample.

The risk-neutral probability π that losses will exceed loss-absorbing capacity in a gone-concern situation is also quite high and depends only slightly on the model choice. In the sample average, the estimated conditional probability π is approximately 50%. As this probability only depends on the parameter λ and the amount of loss-absorbing capacity, it is also fairly stable and does not depend on the amount of stress in credit markets.

6.2 Regional differences

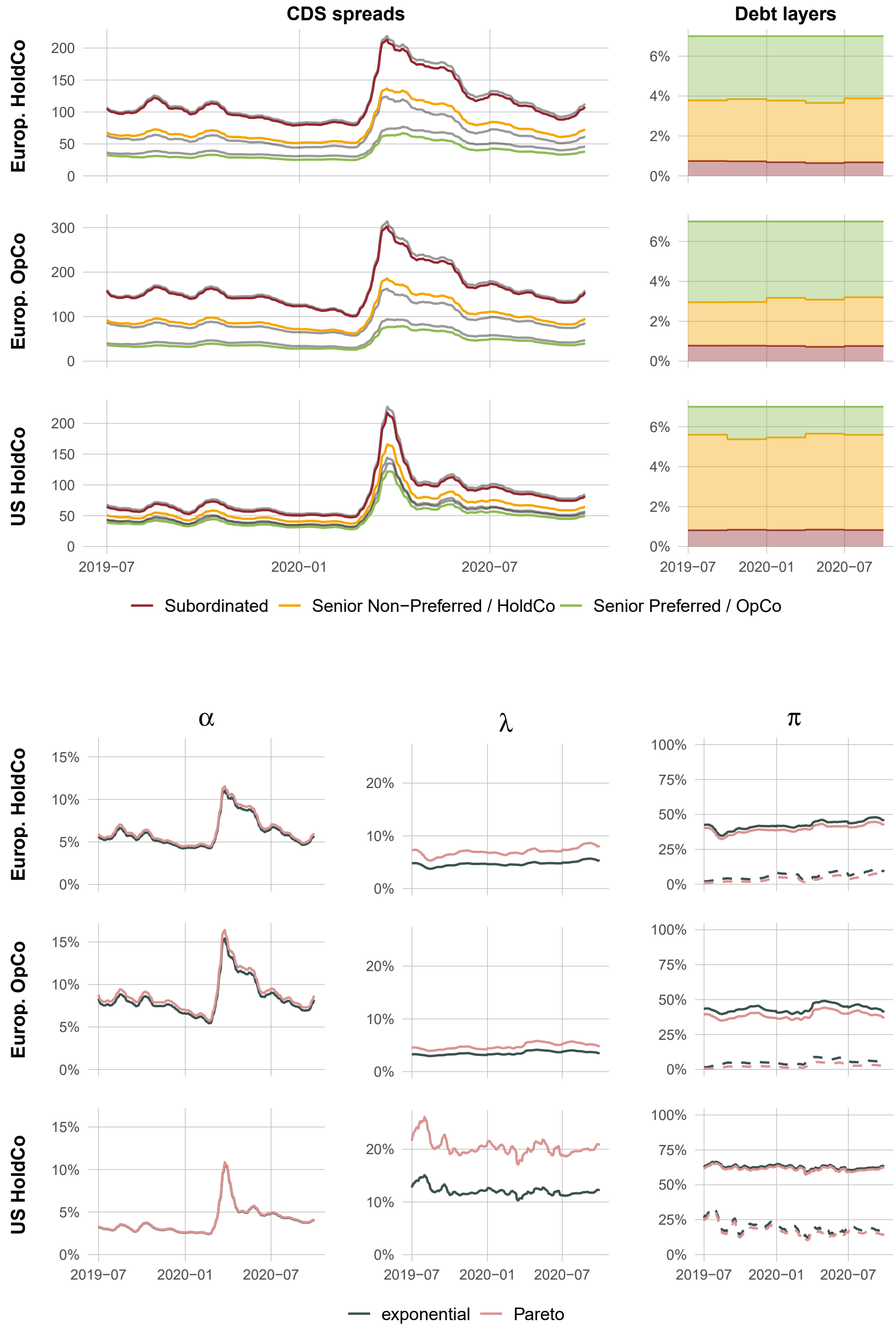
After discussing our main findings for the entire sample, in this subsection we point out a few regional differences. For this purpose, we group the banks in the sample into three groups as shown in Table 3 and show the averaged CDS results separately for each group.

In Figure 6, the US banks show the most noticeable differences to the aggregate results that we have discussed previously. The CDS spreads of the US G-SIBs are compressed and there is almost no difference between OpCo and HoldCo CDS spreads. Such a small bail-in risk premium cannot be explained with our model and, consequently, the fraction of unexplained variance, shown in the lower right panels, is largest for the US banks. A further consequence of these narrow CDS spreads is that the estimated loss given a gone-concern situation, λ, is very high (more than 10% of LRE in the exponential model) and quite volatile. The US G-SIBs have the thickest layers of bail-in debt but due to the very high expected losses, λ, the probability of losses exceeding TLAC, π, is higher than the average 50% for these banks.

The European G-SIBs that issue bail-in debt as senior non-preferred debt show much wider CDS spreads. For these banks, the expected losses, λ, are the lowest and quite stable. At the same time, these banks have the lowest amount of bail-in debt outstanding. For this reason, the probability π of losses exceeding this relatively thin loss-absorbing debt layer in a gone-concern situation is not much lower than the average 50%, despite the relatively low λ.

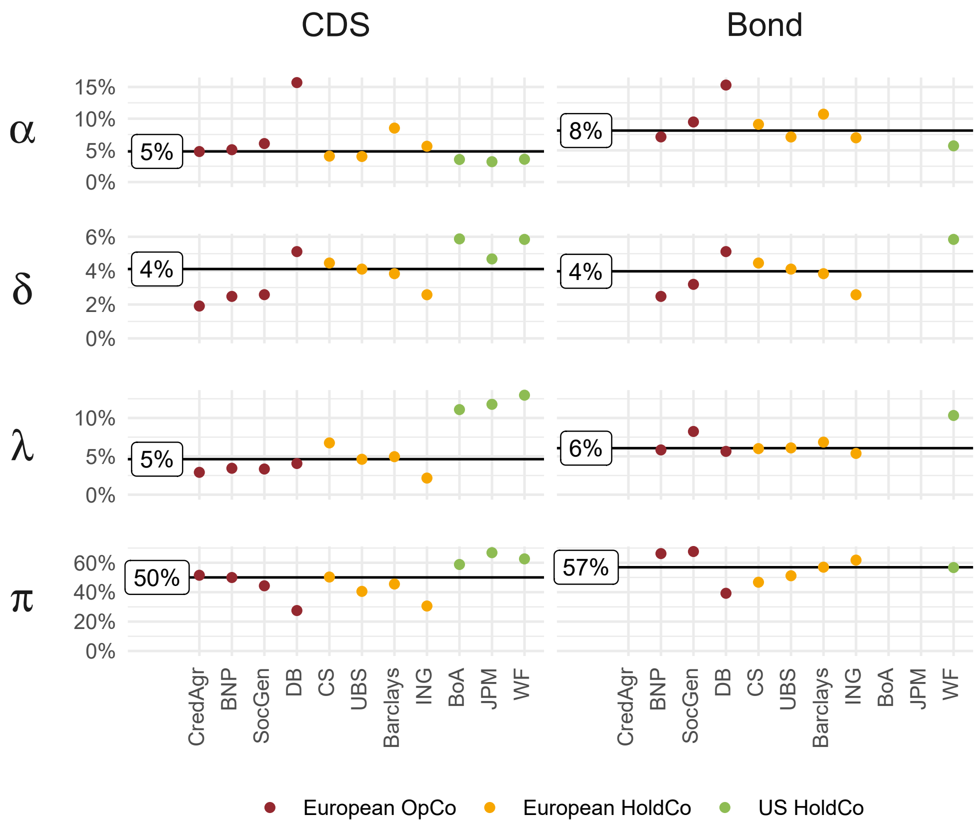
The European G-SIBs that issue bail-in debt out of their HoldCo lie between the previous two groups. The difference between the HoldCo and OpCo CDS spreads is narrow but not as narrow as that for the US G-SIBs. This group also ranks between US banks the other European banks in terms of the outstanding bail-in debt.

Figure 6: Time development of CDS spreads, layers, and parameters averaged per bank group



Note: The top panel shows the model-implied (colour) and actual (grey) CDS spreads and the corresponding debt layers. The first two bottom panels show the fitted model parameters α (probability of gone concern) and λ (expected loss given gone concern). The last bottom panel shows the measure π (probability of loss exceeding TLAC given gone concern) together with the fraction of unexplained variance (dashed lines). The fitted spreads in the top panel are shown for the exponential loss function. The measures in the bottom panels are shown for both the exponential and the Pareto loss function. The measures in all panels are averaged over all banks in the group. Debt layers and losses are measured in % of LRE.

Figure 7: Median of estimated parameters per bank



Bank	δ	Spread	α	λ	π	Spread	α	λ	π
CredAgr	1.9	CDS	4.8	2.9	52				
BNP	2.5	CDS	5.1	3.5	50	Bond	7.1	5.8	66
SocGen	2.6	CDS	6.1	3.4	44	Bond	9.5	8.3	68
DB	5.1	CDS	15.7	4.1	28	Bond	15.3	5.7	39
CS	4.5	CDS	4.1	6.8	50	Bond	9.1	6.0	47
UBS	4.1	CDS	4.1	4.6	41	Bond	7.1	6.1	51
Barclays	3.8	CDS	8.5	5.0	46	Bond	10.7	6.9	57
ING	2.6	CDS	5.7	2.2	31	Bond	7.0	5.4	62
BoA	5.9	CDS	3.6	11.1	59				
JPM	4.7	CDS	3.2	11.8	67				
WF	5.8	CDS	3.6	13.0	63	Bond	5.7	10.3	57

Note: The median values of the estimated parameters α (probability of gone concern) and λ (expected loss given gone concern) together with the measure π (probability of loss exceeding TLAC given gone concern). The parameters are estimated using the exponential loss distribution based on CDS and, if available, bond spreads. δ shows the thickness of the loss-absorbing debt layers (Tier 2 and bail-in debt). Total long-term unsecured debt is assumed to be 7%. Debt layers and losses are expressed in % of LRE and the other numbers are in %. The black lines denote the median values.

6.3 Bank specific results based on bond and CDS data

Figure 7 summarises CDS and bond results by showing the median values of the estimated parameters per bank. The figure shows the results obtained with an exponential loss distribution. The same figure with the Pareto loss distribution is shown in Appendix A.4. The charts with the time-dependent CDS and bond spread results for each bank are shown in Appendix A.5 and A.6, respectively.

If we compare the results based on bond spreads to the results based on CDS spreads, we see that the parameter α is higher for bonds than for CDS spreads. This reflects the empirical fact the bond spreads are typically higher than CDS spreads for financial firms (negative CDS-bond basis). The comparison shows also that expected loss estimates, λ, are quite similar for bond and CDS spreads. For the European banks, the λ estimated with bond data is generally somewhat higher and for Wells Fargo, the only US G-SIB for which we have found a complete set of bond data, the λ is lower. For Wells Fargo and, to a lesser extent, some European banks, we observe that bond spreads trade wider after the Covid-19 market turbulence (cf. Appendix A.6). Consequently, the estimated λ is reduced after the market turbulence. This is a further difference to the CDS results, where no such change in λ can be observed.

As a reference, we have also included in Figure 7 the median amount of loss-absorbing debt (Tier 2 instruments and bail-in debt) as a percentage of LRE and we have denoted it as δ. For almost all banks, except Deutsche Bank and ING, the expected loss estimate, λ, is higher than the amount of loss-absorbing debt. Only for Crédit Agricole and ING the expected loss, λ, is smaller than the international TLAC debt requirement of 3.75%.

The results for the loss parameter λ are quite comparable between banks that belong to the same group. The results for the parameter α vary more between banks in the same group. Notably, α is significantly higher for Deutsche Bank than for the French banks due to the overall higher CDS spreads of Deutsche Bank.

7 Discussion and Policy Implications

Our estimates for the risk-neutral losses in a gone-concern situation are quite large compared to the regulatory requirements for TLAC. This raises the question whether the regulatory objective of TLAC, to ensure sufficient loss-absorbing capacity for an orderly resolution with a high degree of confidence, has been achieved.

For this discussion, the distinction between real-world probabilities and risk-neutral probabilities is relevant. As our method relies entirely on market prices, it can provide only risk-neutral probabilities and loss parameters. Generally, we know that credit market participants are risk-averse. This means that the credit risk premium paid by bond investors is larger than the actual credit losses they suffer in the long-term average. Therefore, our risk-neutral loss estimates may also be larger than the losses that have to be expected in an actual gone-concern situation.[14]

[14]This point is actually quite subtle. If the ratio between risk-neutral and risk-averse credit spreads were constant

It is not the objective of this paper, however, to predict the actual losses in the resolution of a G-SIB or to provide a new calibration for the TLAC requirements. Ultimately, we have to recognize that the real-world probabilities and the expected losses for the resolution of a G-SIB cannot be determined very accurately at this point. Not a single G-SIB has been resolved so far under the new regulatory framework and therefore the uncertainty about the actual losses that would occur in such a scenario remains very large, for both regulators and market participants.

The point we are making in this paper is that the pricing of bail-in debt relative to other debt instruments appears to be at odds with the objectives of the regulatory bail-in concept. The TLAC requirements should provide sufficient bail-in debt to absorb the expected losses in resolution and this bail-in debt should absorb losses prior to other debt that is not eligible for TLAC. Our results imply, however, that market participants expect a probability of approximately 50% that losses will exceed TLAC in a gone-concern situation, if we assume that bail-in debt absorbs losses prior to other senior debt. According to this finding, market participants are not convinced that G-SIBs have sufficient bail-in debt to absorb losses in a gone-concern situation or, alternatively, that it will absorb losses prior to other senior liabilities.

This result persists even under stressed market conditions, like the global market shock that occurred due to the Covid-19 pandemic. If market participants were convinced that only bail-in debt but not other senior debt would be subject to losses in a gone-concern situation, only the spread of bail-in debt would increase during such a market turbulence. This is clearly not the case. Our model shows that in a stress situation market participants expect that a gone-concern situation has become more likely, but their expectations about the losses in such a gone-concern situation does not change.

This finding should be a concern to policymakers, as it could interfere with the regulatory resolution plans. For a successful resolution, it is critical that market participants keep trust in the operating liabilities of a G-SIB. If credit market participants cannot be convinced that certain liabilities will continue to perform, it will be much more difficult for regulators to perform an orderly resolution of a G-SIB. If the resolution gets out of control, losses may be much higher than under an orderly resolution and the market participants' large loss expectation could become, to some extent, a self-fulfilling prophecy.

Therefore, regulators should try to establish a clear distinction between bail-in debt and senior debt, such that there remains no room for doubt that bail-in debt is going to absorb losses prior to senior debt in a resolution. One possibility for making this distinction quite clear would be to request that bail-in debt must be contractually subordinated (Tier 2) CoCos. Investors do make a clear price distinction between these instruments and normal senior debt. There may be other pos-

for a given issuer, it would only affect the overall scaling factor α in our model but not the expected loss parameter λ. Empirical analysis shows, however, that the ratio of market-implied credit losses to actually observed credit losses is not uniform for all bonds categories but rather increases with the credit rating of the bond (cf. e.g. Hull (2005)). Therefore, we can expect that not only the model parameter α but also the model parameter λ could be reduced by a translation of the risk-neutral to the real-world measure. Such a translation of risk-neutral loss parameters to real-world loss parameters could be attempted, in principle, but would be strongly dependent on assumptions and is, therefore, beyond the scope of this paper.

sibilities to achieve the same objective. Our analysis suggests that making the distinction explicit helps. The legal distinction between senior preferred and senior non-preferred debt, as it has been introduced in the EU, leads already to a better price distinction than structural subordination.

So far, banks have been resisting such initiatives quite successfully. Regulators have allowed that banks promote their bail-in debt as senior debt without contractual subordination. This marketing strategy made it possible for banks to issue bail-in debt with only a small risk premium compared to other senior debt. At the same time, this lack of distinction has negatively affected the funding costs for other senior debt, because the loss protection, which a large subordinated debt layer would provide to senior debt holders, is not sufficiently transparent or credible.

Despite these protection benefits, it is probably true that a clear contractual subordination and loss-absorption for bail-in debt would lead to a net increase of banks' funding costs. Such an increase in funding costs would, however, be in line with the objective of the TBTF reforms, to reduce TBTF subsidies end to establish credible resolution strategies.

8 Conclusion

In this paper, we introduce a parametric, structural credit model, which is based on standard risk-neutral pricing theory. Similar to other risk-neutral pricing models, the parameters of this model can be calibrated based on observed market prices. In this way, we estimate the risk-neutral probability of a gone-concern situation and the risk-neutral expected loss in a gone-concern situation from the credit spreads of debt instruments with different seniorities.

The risk-neutral expected losses that we estimate with this approach are quite robust. The difference between the loss estimates based on CDS and bond spreads is relatively small. Furthermore, we show that different assumptions and parametrisations have little impact and that they tend to increase, rather than decrease, the expected losses. We also show that our estimates for the expected losses in gone-concern situations do not change if we go from a normal to a stressed market environment.

We find that the estimated risk-neutral losses in a gone-concern situation are large compared to the regulatory requirements for bail-in debt. Consequently, the risk-neutral probability of losses exceeding the standard calibration of loss-absorbing capacity is also large. Under the risk-neutral measure, for most banks it is more likely than not that the losses in a gone-concern situation exceed the loss absorbing capacity.

Our estimates rely entirely on market prices and, as investors tend to be risk averse, we do not claim that it can be used to calibrate TLAC requirements. We point out, however, that the current pricing of TLAC instruments raises concerns regarding the regulatory bail-in concept. If market participants do not believe that primarily bail-in debt will be subject to losses in a gone-concern situation, it will be difficult to convince them that the liabilities of the operating bank entities will continue to perform.

Even if regulators believe that the available loss-absorbing capacity of their G-SIB will be sufficient for a successful resolution, it seems imprudent to ignore these market-based loss estimates.

If already in a turbulent market environment the credit spreads of non-eligible debt instruments increase sharply and are strongly correlated with the spreads of bail-in debt, we have to assume that market participants would shun these and other senior liabilities of the bank even more in a gone-concern situation. This could have severe negative consequences on the funding and the operations of the G-SIB and could jeopardise an orderly resolution.

In terms of policy implications, our results suggest that regulators should promote clarity and legal certainty that bail-in debt absorbs losses prior to operational and excluded liabilities. This could be achieved by a clearer subordination and by more explicit, contractual conversion mechanisms. This should eventually lead to a more differentiated pricing of bail-in debt with respect to other debt.

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A Appendix

A.1 Bond and CDS static data

Bank	Seniority	ISIN	Ccy	Maturity
CS	Subordinated	XS0957135212	USD	2023-08-08
CS	Senior HoldCo	US225433AC55	USD	2025-03-26
CS	Senior OpCo	US22546QAP28	USD	2024-09-09
UBS	Subordinated	US90261AAB89	USD	2022-08-17
UBS	Senior HoldCo	CH0302790123	EUR	2022-11-16
UBS	Senior OpCo	XS1810806635	EUR	2023-01-23
Barclays	Subordinated	US06738EAC93	USD	2024-09-11
Barclays	Senior HoldCo	US06738EAE59	USD	2025-03-16
Barclays	Senior OpCo	US06739FHV67	USD	2024-05-15
ING	Subordinated	USN45780CT38	USD	2023-09-25
ING	Senior HoldCo	XS1576220484	EUR	2022-03-09
ING	Senior OpCo	XS0748187902	EUR	2022-02-21
BNP	Subordinated	XS1190632999	EUR	2025-02-17
BNP	Senior Non-Preferred	XS1808338542	EUR	2024-04-17
BNP	Senior Preferred	XS1068871448	EUR	2024-05-20
SocGen	Subordinated	XS1195574881	EUR	2025-02-27
SocGen	Senior Non-Preferred	FR0013311503	EUR	2025-01-23
SocGen	Senior Preferred	FR0013486701	EUR	2026-02-24
DB	Subordinated	DE000DB7XJJ2	EUR	2025-02-17
DB	Senior Non-Preferred	DE000DB5DCS4	EUR	2023-01-11
DB	Senior Preferred	DE000DL19UC0	EUR	2023-08-30
WF	Subordinated	USU94974AL37	USD	2024-01-16
WF	Senior HoldCo	US95000U2C66	USD	2024-01-24
WF	Senior OpCo	US94988J5R41	USD	2023-08-14

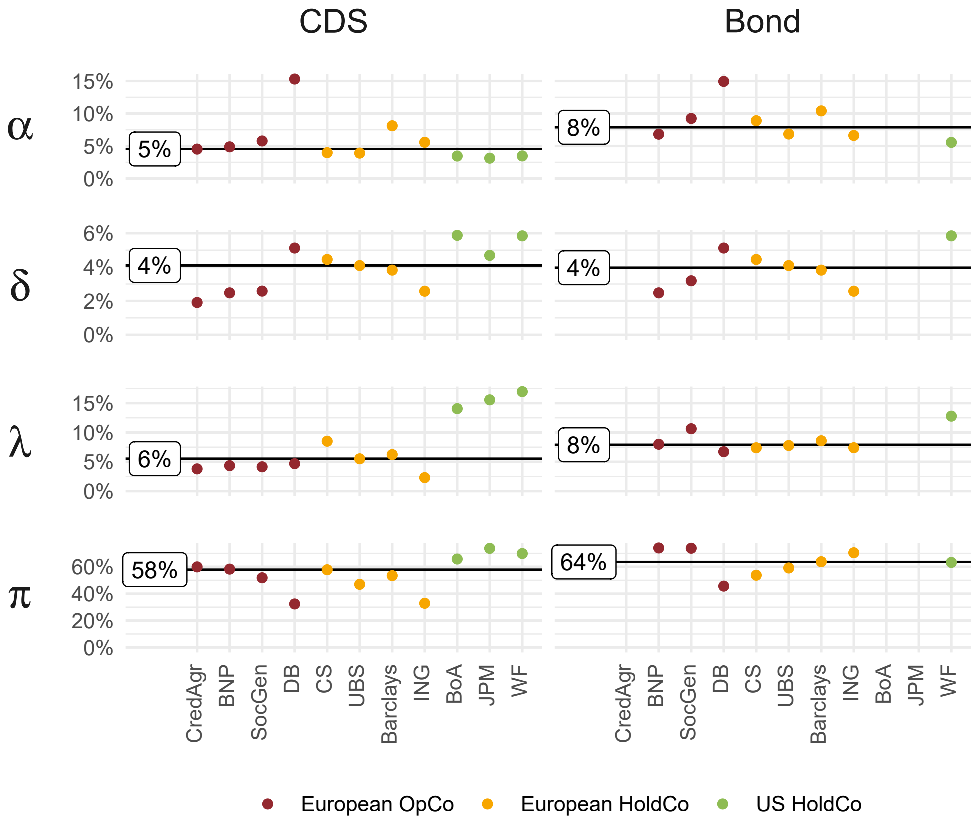
Table A.1: The bonds used in the bond spread analysis. For each bank, we have selected three liquid and unsecured long-term bonds with a maturity of approximately five years. The bonds spreads are the benchmark spreads as calculated by Refinitiv.

Bank	Seniority	Markit Code	Sen. Code
CS	Subordinated	CSGAG	SUBLT2
CS	Senior HoldCo	CSGAG	SNRFOR
CS	Senior OpCo	CRDSUI-CSAG	SNRFOR
UBS	Subordinated	UBS	SUBLT2
UBS	Senior HoldCo	UBSGRO	SNRFOR
UBS	Senior OpCo	UBS	SNRFOR
Barclays	Subordinated	BACR	SUBLT2
Barclays	Senior HoldCo	BACR	SNRFOR
Barclays	Senior OpCo	BACR-Bank	SNRFOR
ING	Subordinated	INTNED	SUBLT2
ING	Senior HoldCo	INTNED	SNRFOR
ING	Senior OpCo	INTNED-BankNV	SNRFOR
CredAgr	Subordinated	ACAFP	SUBLT2
CredAgr	Senior Non-Preferred	ACAFP	SNRLAC
CredAgr	Senior Preferred	ACAFP	SNRFOR
BNP	Subordinated	BNP	SUBLT2
BNP	Senior Non-Preferred	BNP	SNRLAC
BNP	Senior Preferred	BNP	SNRFOR
SocGen	Subordinated	SOCGEN	SUBLT2
SocGen	Senior Non-Preferred	SOCGEN	SNRLAC
SocGen	Senior Preferred	SOCGEN	SNRFOR
DB	Subordinated	DB	SUBLT2
DB	Senior Non-Preferred	DB	SNRLAC
DB	Senior Preferred	DB	SNRFOR
BoA	Subordinated	BACORP	SUBLT2
BoA	Senior HoldCo	BACORP	SNRFOR
BoA	Senior OpCo	BACF-BankNA	SNRFOR
JPM	Subordinated	JPM	SUBLT2
JPM	Senior HoldCo	JPM	SNRFOR
JPM	Senior OpCo	JPM-ChaseBkNA	SNRFOR
WF	Subordinated	WFC	SUBLT2
WF	Senior HoldCo	WFC	SNRFOR
WF	Senior OpCo	WFC-BankNA	SNRFOR

Table A.2: The CDS data are obtained from Markit. We use the five year tenor and the Markit legal entity codes and seniority codes as shown in the table above. For European (US) banks we use the currency EUR (USD) and the doc clause MM14 (XR14). The CDS spread is the ParSpread as calculated by Markit.

A.2 Results assuming 10% of long-term debt

Figure A.1: Median of estimated parameters per bank assuming 10% of long-term debt



Bank	δ	Spread	α	λ	π	Spread	α	λ	π
CredAgr	1.9	CDS	4.5	3.8	60				
BNP	2.5	CDS	4.9	4.4	58	Bond	6.8	8.0	74
SocGen	2.6	CDS	5.8	4.2	52	Bond	9.3	10.6	74
DB	5.1	CDS	15.3	4.7	32	Bond	14.9	6.7	46
CS	4.5	CDS	4.0	8.5	58	Bond	8.9	7.4	54
UBS	4.1	CDS	3.9	5.5	47	Bond	6.9	7.8	59
Barclays	3.8	CDS	8.1	6.2	53	Bond	10.4	8.6	64
ING	2.6	CDS	5.6	2.3	33	Bond	6.6	7.4	71
BoA	5.9	CDS	3.5	14.1	66				
JPM	4.7	CDS	3.1	15.6	74				
WF	5.8	CDS	3.5	17.0	70	Bond	5.6	12.8	63

Note: The median values of the estimated parameters α (probability of gone concern) and λ (expected loss given gone concern) together with the measure π (probability of loss exceeding TLAC given gone concern). The parameters are estimated using the exponential loss distribution based on CDS and, if available, bond spreads. δ shows the thickness of the loss-absorbing debt layers (Tier 2 and bail-in debt). Total long-term unsecured debt is assumed to be 10%. Debt layers and losses are expressed in % of LRE and the other numbers are in %. The black lines denote the median values.

A.3 Technical details of the parameter fitting

If we have more than two layers, we can determine the parameters α and λ such that they minimise the sum of the squared differences between model-implied and observed spreads. For small spreads, the spread s_i is proportional to the expected loss l_i (see Eq. (8)) and, for simplicity, we can directly minimise the sum of the squared differences between model-implied and observed expected losses. Similar to Eq. (7), we define the observed expected loss of debt layer i as $\hat{l}_i = 1 - e^{-\hat{s}_i T}$, where $\hat{s}_i$ is the observed spread for the debt layer i. Depending on our choice with respect to absolute or relative differences, we have to minimise the following expressions:

$$\sum_i (l_i - \hat{l}_i)^2 \quad \text{or} \quad \sum_i \frac{(l_i - \hat{l}_i)^2}{\hat{l}_i^2}. \tag{17}$$

Setting the partial derivatives with respect to α and λ to zero, we obtain the following two equations for absolute differences:

$$0 = \sum_i (l_i - \hat{l}_i)\frac{l_i}{\alpha} \quad \text{and} \quad 0 = \sum_i (l_i - \hat{l}_i)\frac{\partial l_i}{\partial \lambda}. \tag{18}$$

and the following two equations for relative differences:

$$0 = \sum_i \frac{l_i - \hat{l}_i}{\hat{l}_i^2}\frac{l_i}{\alpha} \quad \text{and} \quad 0 = \sum_i \frac{l_i - \hat{l}_i}{\hat{l}_i^2}\frac{\partial l_i}{\partial \lambda}. \tag{19}$$

If we introduce the α-independent quantities $\tilde{l}_i = l_i/\alpha$, we can solve the first equations for alpha:

$$\alpha = \frac{\sum_i \hat{l}_i \tilde{l}_i}{\sum_i \tilde{l}_i^2} \quad \text{or} \quad \alpha = \frac{\sum_i \tilde{l}_i / \hat{l}_i}{\sum_i \tilde{l}_i^2 / \hat{l}_i^2}. \tag{20}$$

For the partial derivative with respect to λ, we obtain in the exponentially decaying model

$$\frac{\partial l_{\exp,i}}{\partial \lambda} = \frac{l_{\exp,i}}{\lambda}\left(1 - \frac{L_i^+}{\lambda}\right) - \frac{\alpha}{\lambda} e^{-L_i^-/\lambda}. \tag{21}$$

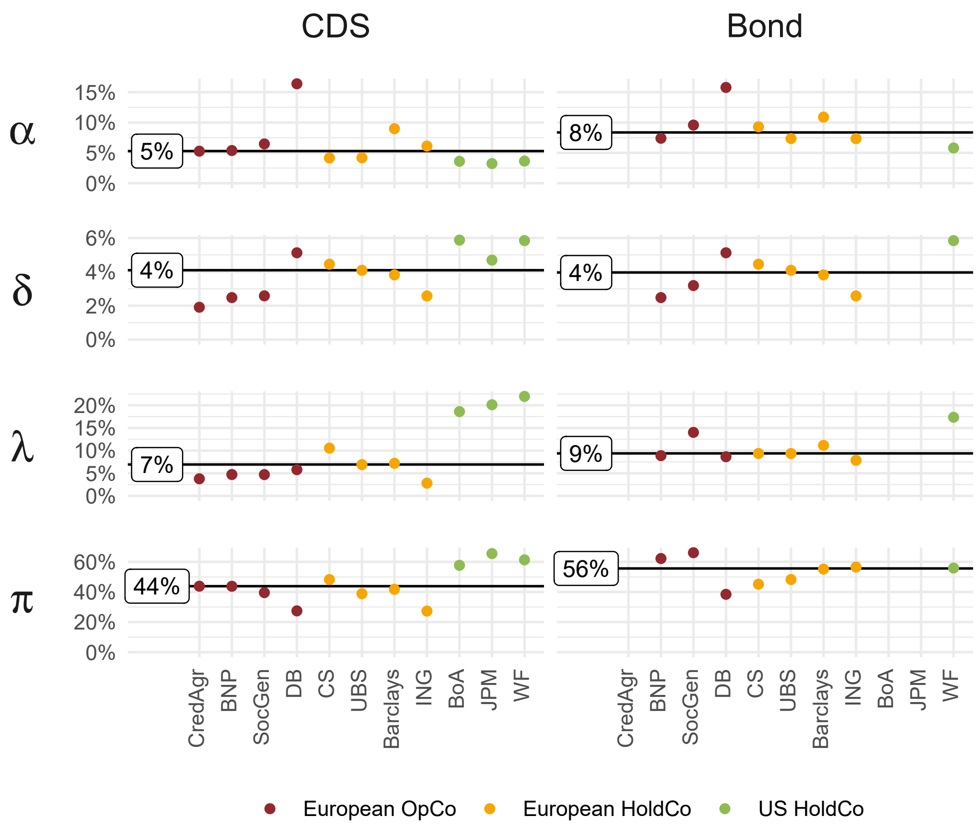
and in the Pareto model

$$\frac{\partial l_{\mathrm{Pareto},i}}{\partial \lambda} = l_{\mathrm{Pareto},i}\left(\frac{2}{\lambda} - \frac{1}{L^- + \lambda} - \frac{1}{L^+ + \lambda}\right). \tag{22}$$

Substituting α with the formulas in Eq. (20), we can determine λ by solving a one-dimensional root-finding problem, which is numerically very cheap. The results presented are obtained by minimising the absolute differences. We find no material differences if we minimise the relative differences.

A.4 Results based on the Pareto distribution

Figure A.2: Median of estimated parameters per bank based on the Pareto loss distribution

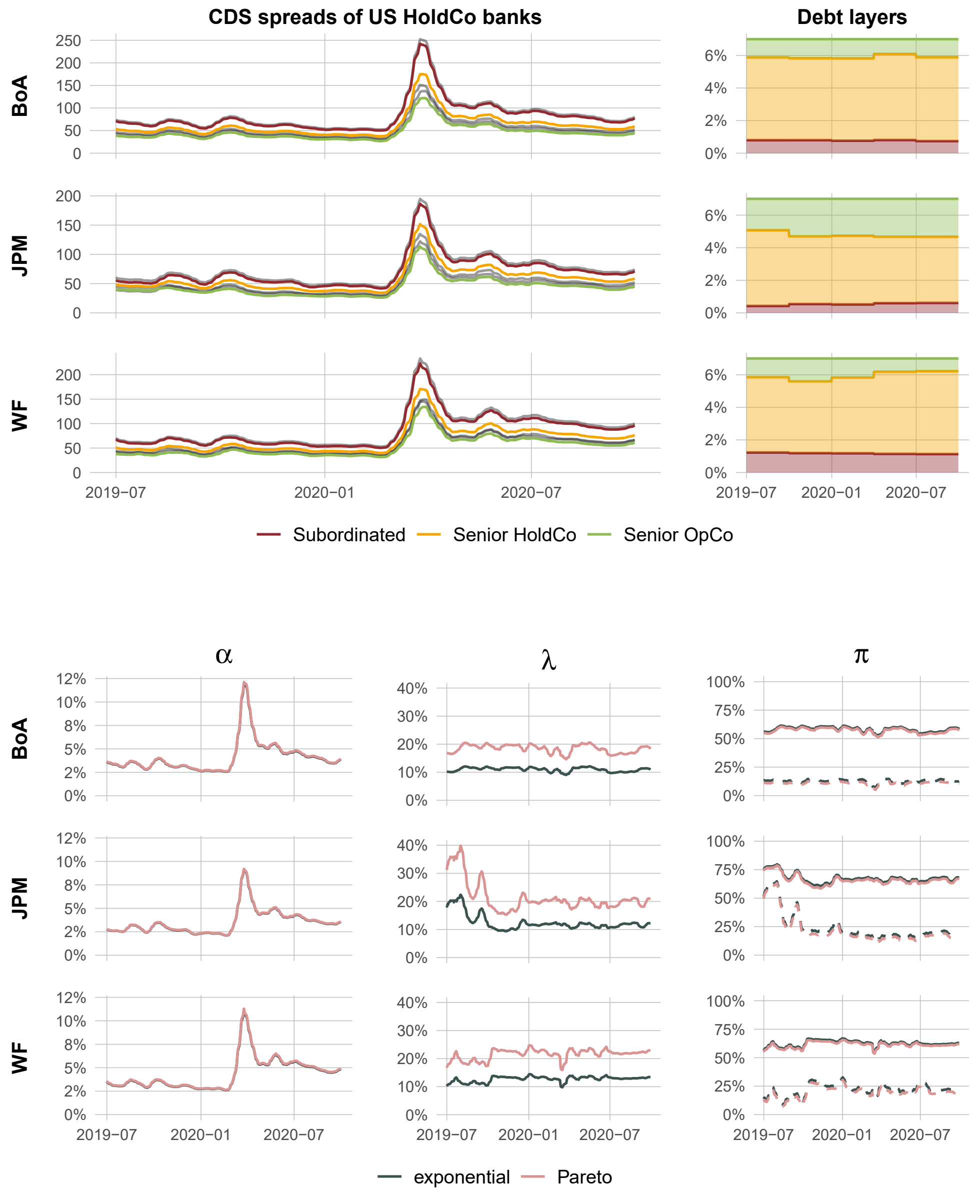


Bank	δ	Spread	α	λ	π	Spread	α	λ	π
CredAgr	1.9	CDS	5.3	3.8	44				
BNP	2.5	CDS	5.4	4.7	44	Bond	7.4	8.9	62
SocGen	2.6	CDS	6.5	4.7	40	Bond	9.6	14.0	66
DB	5.1	CDS	16.4	5.8	27	Bond	15.8	8.7	39
CS	4.5	CDS	4.2	10.6	48	Bond	9.3	9.4	45
UBS	4.1	CDS	4.2	6.9	39	Bond	7.4	9.4	48
Barclays	3.8	CDS	9.0	7.2	42	Bond	10.9	11.2	55
ING	2.6	CDS	6.1	2.8	27	Bond	7.4	7.9	57
BoA	5.9	CDS	3.6	18.6	58				
JPM	4.7	CDS	3.3	20.1	66				
WF	5.8	CDS	3.7	22.0	61	Bond	5.8	17.4	56

Note: The median values of the estimated parameters α (probability of gone concern) and λ (expected loss given gone concern) together with the measure π (probability of loss exceeding TLAC given gone concern). The parameters are estimated using the Pareto loss distribution based on CDS and, if available, bond spreads. δ shows the thickness of the loss-absorbing debt layers (Tier 2 and bail-in debt). Total long-term unsecured debt is assumed to be 7%. Debt layers and losses are expressed in % of LRE and the other numbers are in %. The black lines denote the median values.

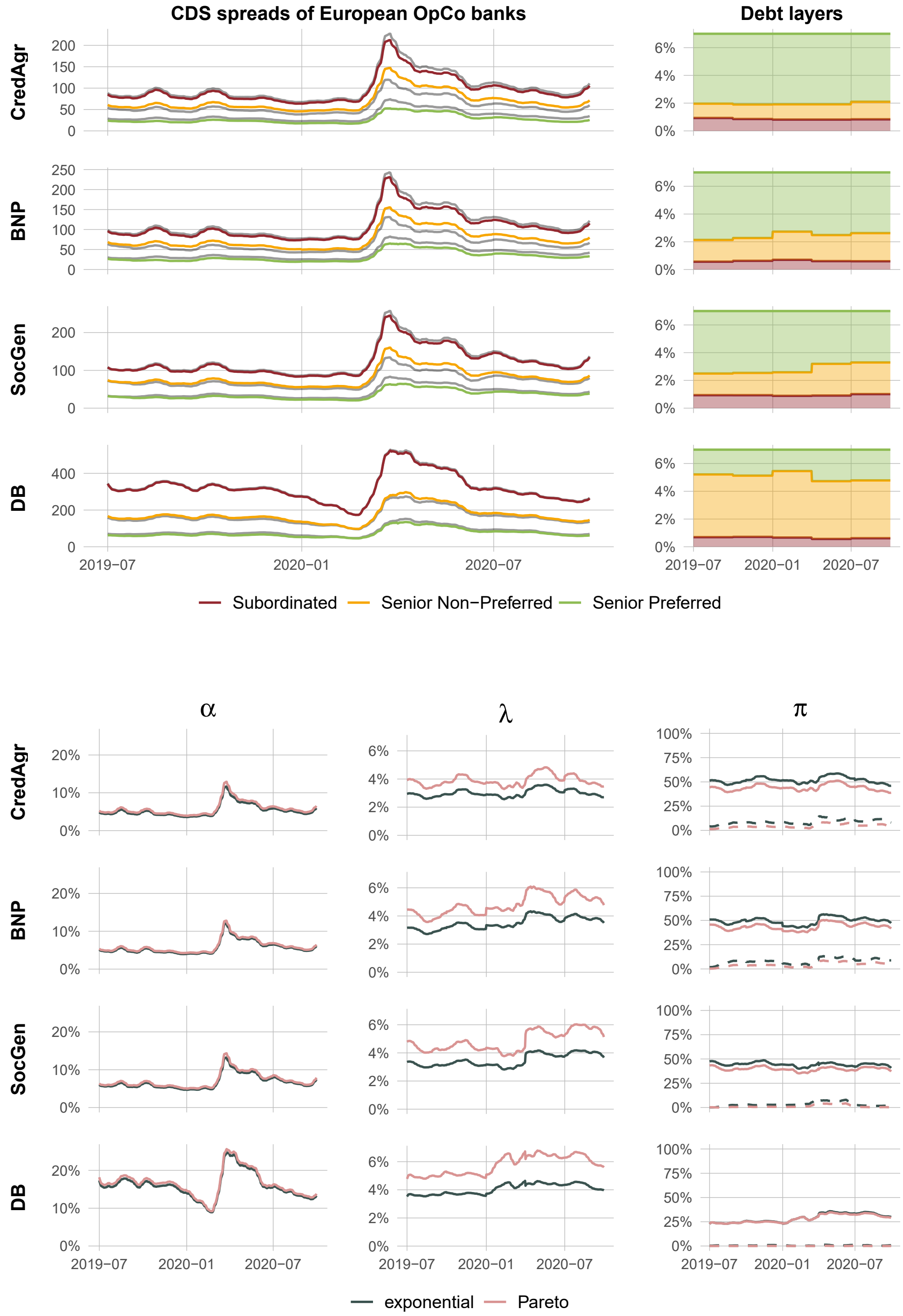
A.5 CDS results per Bank

Figure A.3: Time development of CDS spreads, layers, and parameters for US HoldCo banks



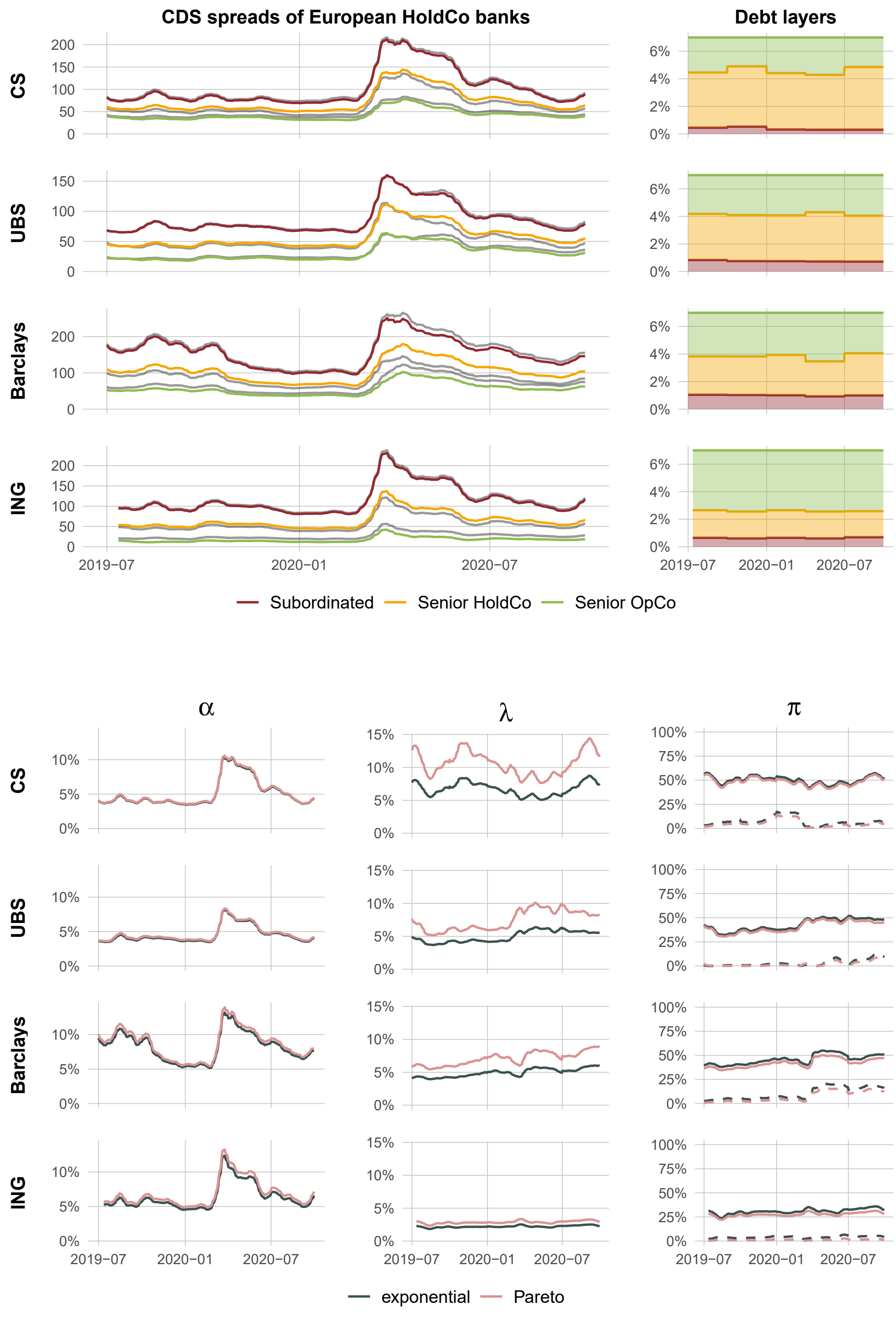
Note: The top panel shows the model-implied (colour) and actual (grey) CDS spreads and of the corresponding debt layers for 3 US HoldCo banks. The first two bottom panels show the fitted model parameters α (probability of gone concern) and λ (expected loss given gone concern). The last bottom panel shows the measure π (probability of loss exceeding TLAC given gone concern) together with the fraction of unexplained variance (dashed lines). The fitted spreads in the top panel are shown for the exponential loss function. The measures in the bottom panels are shown for both the exponential and the Pareto loss function. Debt layers and losses are measured in % of LRE.

Figure A.4: Time development of CDS spreads, layers, and parameters for European OpCo banks



Note: The top panel shows the model-implied (colour) and actual (grey) CDS spreads and of the corresponding debt layers for 4 European OpCo banks. The first two bottom panels show the fitted model parameters α (probability of gone concern) and λ (expected loss given gone concern). The last bottom panel shows the measure π (probability of loss exceeding TLAC given gone concern) together with the fraction of unexplained variance (dashed lines). The fitted spreads in the top panel are shown for the exponential loss function. The measures in the bottom panels are shown for both the exponential and the Pareto loss function. Debt layers and losses are measured in % of LRE.

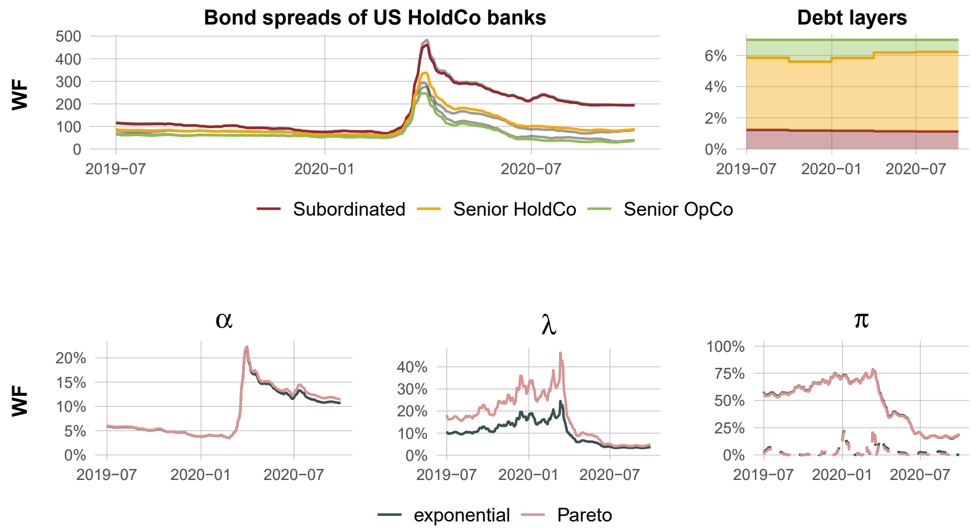
Figure A.5: Time development of CDS spreads, layers, and parameters for European HoldCo banks



Note: The top panel shows the model-implied (colour) and actual (grey) CDS spreads and of the corresponding debt layers for 4 European HoldCo banks. The first two bottom panels show the fitted model parameters α (probability of gone concern) and λ (expected loss given gone concern). The last bottom panel shows the measure π (probability of loss exceeding TLAC given gone concern) together with the fraction of unexplained variance (dashed lines). The fitted spreads in the top panel are shown for the exponential loss function. The measures in the bottom panels are shown for both the exponential and the Pareto loss function. Debt layers and losses are measured in % of LRE.

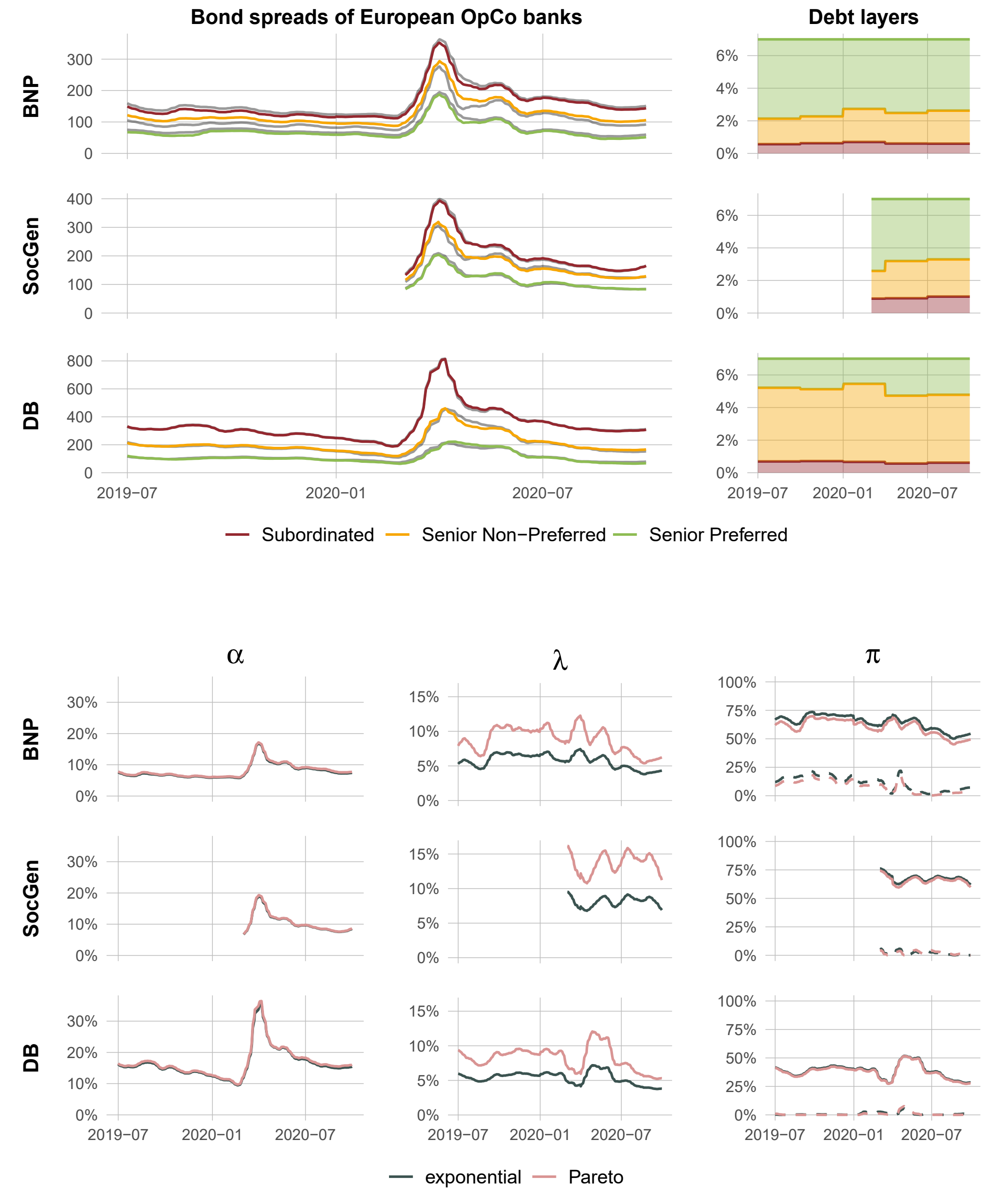
A.6 Bond results per Bank

Figure A.6: Time development of bond spreads, layers, and parameters for US HoldCo banks



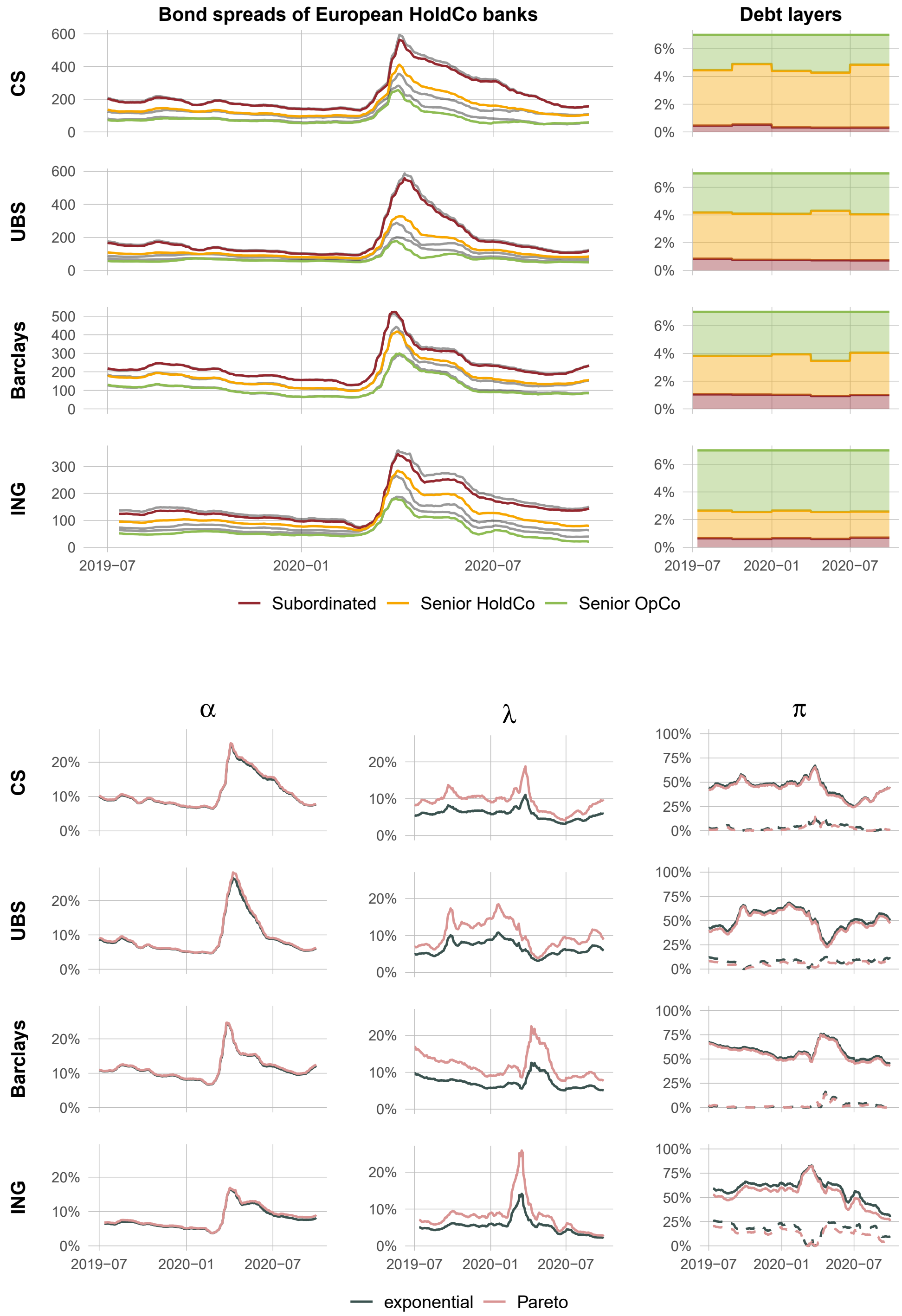
Note: The top panel shows the model-implied (colour) and actual (grey) bond spreads and of the corresponding debt layers for the US bank Wells Fargo. The first two bottom panels show the fitted model parameters α (probability of gone concern) and λ (expected loss given gone concern). The last bottom panel shows the measure π (probability of loss exceeding TLAC given gone concern) together with the fraction of unexplained variance (dashed lines). The fitted spreads in the top panel are shown for the exponential loss function. The measures in the bottom panels are shown for both the exponential and the Pareto loss function. Debt layers and losses are measured in % of LRE.

Figure A.7: Time development of bond spreads, layers, and parameters for European OpCo banks



Note: The top panel shows the model-implied (colour) and actual (grey) bond spreads and of the corresponding debt layers for 3 European OpCo banks. The first two bottom panels show the fitted model parameters α (probability of gone concern) and λ (expected loss given gone concern). The last bottom panel shows the measure π (probability of loss exceeding TLAC given gone concern) together with the fraction of unexplained variance (dashed lines). The fitted spreads in the top panel are shown for the exponential loss function. The measures in the bottom panels are shown for both the exponential and the Pareto loss function. Debt layers and losses are measured in % of LRE.

Figure A.8: Time development of bond spreads, layers, and parameters for European HoldCo banks



Note: The top panel shows the model-implied (colour) and actual (grey) bond spreads and of the corresponding debt layers for 4 European HoldCo banks. The first two bottom panels show the fitted model parameters α (probability of gone concern) and λ (expected loss given gone concern). The last bottom panel shows the measure π (probability of loss exceeding TLAC given gone concern) together with the fraction of unexplained variance (dashed lines). The fitted spreads in the top panel are shown for the exponential loss function. The measures in the bottom panels are shown for both the exponential and the Pareto loss function. Debt layers and losses are measured in % of LRE.

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