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From Incurred to Expected Loss: Implications for Bank Lending

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Abstract

The Great Recession prompted a shift in accounting standards for banks' loan loss provisioning from an incurred loss approach to an expected credit loss approach. This paper develops and calibrates a dynamic banking model featuring a recursive ratings-migration structure for loan credit quality to evaluate the impact of the new standards on bank performance. We quantify the implications for bank lending, including its increased sensitivity to economic conditions, and examine the trade-offs involved in using Basel III's countercyclical capital buffer as a stabilizing policy tool.

JEL Codes: G21, G28, M41.

Keywords: Loan loss provisions, expected credit losses, incurred losses, rating migrations, procyclicality.

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1 Introduction

Banks' delayed recognition of credit losses under the incurred loss (IL) approach to loan loss provisioning was argued to have contributed to the severity of the Global Financial Crisis (Financial Stability Forum, 2009). By provisioning "too little, too late," it might have made banks less prepared to absorb losses in good times and less pressed for prompt corrective action in bad times. The G-20 call for a more forward-looking approach resulted in the adoption of IFRS 9 by the International Accounting Standards Board and the so-called current expected credit loss (CECL) model by the US Financial Accounting Standards Board (US GAAP Topic 326).[1] Both reforms coincide in adopting an expected credit loss (ECL) approach to provisioning.

Under the new approach, loan loss provisions are intended to represent best unbiased estimates of the discounted credit losses expected to emerge over some specified horizons. In the case of IFRS 9, the horizon depends on the credit quality of the exposures. For assets without a significant deterioration in credit quality since origination (classified as "stage 1"), the horizon is one year. For exposures with deteriorated credit quality ("stage 2") or already impaired ("stage 3"), provisions extend to the residual lifetime of the credit instrument. In contrast, the CECL model of US GAAP opts for using the residual lifetime horizon for all exposures, regardless of credit quality.

The general perception is that ECL approaches increase the reliability of bank capital as a measure of solvency and facilitate prompt corrective action in bad times (Cohen and Edwards, 2017). There are concerns, however, that ECL approaches may also increase the equity funding required per unit of new lending at all times, and that their reliance on point-in-time forward-looking estimates may imply a more abrupt deterioration of profits and a surge in capital needs when the economy enters a recession or a crisis starts. This could affect credit supply and amplify the cyclicality of provisions, capital, and lending relative to

[1] See International Accounting Standards Board (2014) and Financial Accounting Standards Board (2016) for details. IFRS 9 and CECL were planned to be applied from 2018 and 2020, respectively, but the arrival of the Covid-19 pandemic led to the delay of their full implementation in several jurisdictions due to concerns about potential procyclical effects (see European Central Bank, 2020).

the IL approach (see e.g. European Systemic Risk Board, 2017).[2]

This paper quantitatively explores the impact of the new provisioning standards on the level and cyclicality of bank performance, with a particular focus on the effects on bank lending. To achieve this goal, we consider the dynamic optimization problem of a representative bank that extends long-lived loans and is financed with an endogenous combination of insured deposits and internally-accumulated equity. A novel feature of the model is its representation of credit risk dynamics using a rating-migration setup, akin to those extensively used in risk management practice (see e.g. Trueck and Rachev, 2009). Exogenous shifts in the cyclical position of the economy (from expansion to contraction and vice versa) affect rating-migration and default probabilities, generating realistic fluctuations in credit risk. The bank responds endogenously to changes in credit risk by adjusting its loan origination, capital structure, and dividend payments. Provisioning standards and regulatory capital requirements, which depend on both realized and expected credit risk, determine the bank's provisioning and capitalization needs, playing a crucial role in the transmission of cyclical shocks.

We calibrate the model to a euro area bank with a typical portfolio of corporate loans and use it to assess the impact of IFRS 9 and CECL on bank behavior, loan origination, and bank solvency, relative to the previous IL standard. Echoing the policy discussion on the main alternatives to address the potential procyclical effects, we also study the effectiveness of the countercyclical capital buffer (CCyB) of Basel III in stabilizing bank credit supply. We quantify the trade-offs (in lending level and solvency terms) implied by the use of this policy tool under alternative design choices differing in the degree to which the effects on the overall capital needs of the bank are offset by permanently reducing other components of the so-called combined buffer requirement (CBR) faced by the bank.

The main findings of the paper can be summarized as follows. First, relative to the IL approach, the new standards imply a larger average level of loan loss provisions, increasing the capital needed to support bank lending and discouraging loan origination. However, the

[2] Basel Committee on Banking Supervision (2021) takes a more cautious stance, arguing that "it is too early for a sound statement to be made" regarding procyclicality, and calling for further research that, in line with the contribution of this paper, takes into account banks' possible behavior changes.

differential effect of the generalized life-time approach in CECL on average level of equity needed to finance one unit of lending makes CECL cause a significantly stronger decline in average lending (13.5%) than IFRS 9 (0.9%), relative to the IL benchmark. Even when the bank is not capital constrained (in the sense that its internally accumulated equity is large enough to pay out discretionary dividends), the higher weighted-average cost of funding leads the bank to reduce loan origination, resulting in a smaller average loan portfolio.

Second, the new standards also imply a sharper increase in loan loss provisions at the beginning of contraction periods, thereby amplifying the procyclicality of bank lending. We measure procyclicality as the average difference in total loans between expansions and contractions. We obtain a difference equal to 6.9% under IL, 7.4% under IFRS 9, and 9.4% under CECL. The procyclical effects are due to a combination of profitability effects (contractions involve higher expected losses and subsequently also larger provisioning and capitalization needs, making new lending less profitable) and capital-availability effects (contractions make the bank more likely to be capital-constrained and forced to cut its new lending beyond what pure profitability considerations would dictate). We find that the stronger procyclicality of CECL is mainly due to the profitability effect, while that of IFRS 9 comes, to a larger extent, from the capital-availability effect. The latter is caused by the cliff effects of large reclassifications from stage 1 to stage 2, which increase the likelihood that the bank is unable to comply with capital requirements.

Third, IFRS 9 and CECL also differ in their implications for bank solvency and, more broadly, for the bank's ability to not just comply with the minimum regulatory capital requirement but also avoid the restrictions on dividends and new lending that it would suffer if breaching the CBR. Specifically, relative to the IL baseline, CECL's higher overall capital needs induce the bank to effectively operate with lower leverage, which reduces its probability of failure and the likelihood of being forced to cut dividends and new lending due to equity scarcity. In contrast, IFRS 9 performs very similarly to the IL standard along these dimensions.

Fourth, an active use of the CCyB as a stabilizing policy tool involves non-trivial trade-offs. We identify these trade-offs by comparing two possible designs of the CCyB policy. In both of them, a positive buffer rate of 1% is gradually introduced during expansion phases and then fully released at the beginning of contractions. In the first design, consistent with the choice made by most countries opting for a "positive neutral" CCyB rate in recent years (Basel Committee on Banking Supervision, 2024), the CCyB is added to the benchmark (cyclically invariant) 2.5% level of the CBR. With this design, under any of the three provisioning standards that we study, the average difference in total loans between expansions and contractions is reduced by about 2 percentage points (pp). This policy reduces the cyclicality of lending without increasing the probability of bank failure (which actually slightly declines under the policy). However, it does so at the cost of a significant reduction in average lending. Due to the impact on the cost of funding bank loans during expansions, the policy makes average total loans fall by 5.8% with IL, 5.1% with IFRS 9, and 9.0% with CECL.

In the second design that we analyze, the adoption of the positive neutral rate of 1% for the CCyB comes together with a permanent reduction of 1% in the benchmark level of the CBR, making this design qualify as what is commonly named a "capital neutral" policy (from the point of view of the total capital needs implied in expansion periods). Opposite to the first design, this policy option succeeds at reducing the cyclical variation in total lending without causing a decline in average lending (in fact, total lending increases on average 1.5%, 1.8%, and 3.8% with IL, IFRS 9, and CECL, respectively). The cost in this case comes in the form of a deterioration of bank solvency both unconditionally and during contractions (the bank's probability of failure during contraction periods rises by 0.8, 0.7, and 0.5 pp with IL, IFRS 9, and CECL, respectively).

Related literature This paper is related to three strands of the literature on the procyclicality of loan loss provisions: scenario analyses of ECL standards, structural dynamic banking models with a focus on provisions, and the (mostly empirical) studies that before and after the introduction of ECL standards have focused on provisioning practices and their implications in banking.[3]

[3]The survey in Basel Committee on Banking Supervision (2021) reviews more than ninety papers on provisions, of which only five directly assess the procyclicality of the ECL standards relative to the IL

The literature relying on scenario analysis assesses the effects of ECL standards by simulating their implications during past episodes such as the Global Financial Crisis or broader periods of time. Some studies use data on credit losses during those periods and other historical evidence about the relationship between bank-level or loan-level variables and aggregate financial conditions. The results regarding procyclicality are mixed. Papers including Cohen and Edwards (2017), Chae et al. (2018), DeRitis and Zandi (2018), Loudis and Ranish (2019), and Buesa, Población García, and Tarancón (2020) report mitigating effects of the ECL standards. Papers pointing to procyclical effects include , Krüger, Rösch, and Scheule (2018), Covas and Nelson (2018), and Ryan (2019).

Differently from the previous strand, structural dynamic models are explicit about the stochastic processes followed by the underlying shocks and allow for a consistent representation of banks' endogenous changes in expectations and decisions in response to the evolution of macroeconomic conditions. Prior to the inception of the IFRS 9 and CECL standards, Bouvatier and Lepetit (2012), Agénor and Zilberman (2015), and Agénor and Pereira da Silva (2017) developed structural models to explore the difference that a more forward-looking provisioning regime would make. These papers, however, represented provisions using reduced-form formulas rather than making them explicitly related to credit risk parameters and events, and solved the models using log-linear approximations, thus potentially missing non-linear effects stemming from the occasionally binding nature of capital requirements. More recently, Goncharenko and Rauf (2024) overcome some of these issues by treating the minimum capital requirement as an occasionally binding constraint and by explicitly comparing IL, IFRS 9 and CECL provisions calibrated following Abad and Suarez (2018) but still represented in a stylized manner.[4]

Our paper is also related to the mainly empirical literature that, both prior to and after the introduction of the new ECL standards, examined the effects of loan loss provisioning in

standards.

[4]In contrast to our explicit rating-migration formulation, Goncharenko and Rauf (2024) directly assume that the fractions of "good" (stage 1) and "impaired" (stage 2) loans differ across expansion and contraction periods. In addition, we treat the CBR as a requirement different from the minimum capital requirement. These differences and several calibration details end up making our results quite different from theirs.

banking. Using data prior to the introduction of the ECL approach, several papers, including Laeven and Majnoni (2003), Beatty and Liao (2011), Bushman and Williams (2012, 2015), Huizinga and Laeven (2012), and Wheeler (2019) documented that the decisive and prompt provisioning of credit losses tends to be associated with greater solvency, better resistance to shocks, greater sustainability of credit supply during contractions, and more conservative risk profiles. Papers such as Jiménez et al. (2017), Domikowsky et al. (2014), and Domikowsky, Foos, and Pramor (2015) studied the effects of prior attempts to introduce countercyclical elements in the provisioning standards, including the so-called Spanish statistical provisions. More recently, papers such as López-Espinosa, Ormazabal, and Sakasai (2021), Morais et al. (2021), Chen et al. (2024) have empirically analyzed the implications for bank lending of the new ECL standards, documenting effects on the level and cyclicality of lending consistent with our findings.[5]

2 The model

We consider a bank operating in an infinite-horizon discrete-time economy in which dates are denoted by t and the risk-free rate is constant and equal to r. The economy is subject to cyclical fluctuations represented by an aggregate state $s_t \in S$ that follows a Markov chain with transition probabilities

$$p_{ss'} \equiv \Pr(s_{t+1} = s' | s_t = s) \tag{1}$$

satisfying $\Sigma_{s' \in S} p_{ss'} = 1$; the unconditional probability of being in state s is denoted by $\overline{p}_s$.[6]

The bank is owned by and managed in the interest of wealthy risk-neutral shareholders with a subjective discount factor $\beta < 1/(1+r)$ who receive an endogenous dividend $X_t \geq 0$ from the bank in every period. The bank manages a portfolio of multiperiod loans that

[5] Complementarily, studying U.S. bank holding companies from 2017 to 2021, Kim et al. (2023) claim that the CECL standard improved banks' information production and led to fewer loan defaults.

[6] For simplicity, most of the quantitative analysis in this paper and some explicit formulas below will focus on the case with $S = \{1, 2\}$, where $s = 1$ denotes an expansion state and $s = 2$ denotes a contraction state. However, the analysis can be easily extended to deal with more than two aggregate states.

it originates, and finances its activity with a combination of internally accumulated equity capital and deposits. The credit quality of the individual loans held by the bank in a given period t evolves into the next period according to a Markov process with transition probabilities affected by the realization of the aggregate state in the next period, s_{t+1}. The bank is subject to loan loss provisioning standards and capital requirements that depend on the credit quality of its loans in the corresponding period.

The rest of this section describes, in this order, the dynamics of the bank's loan portfolio, the provisioning standards, the dynamics of the bank's equity, and the capital requirements. We then write the bank's dynamic optimization problem in a recursive manner and explain how we deal with bank failure.

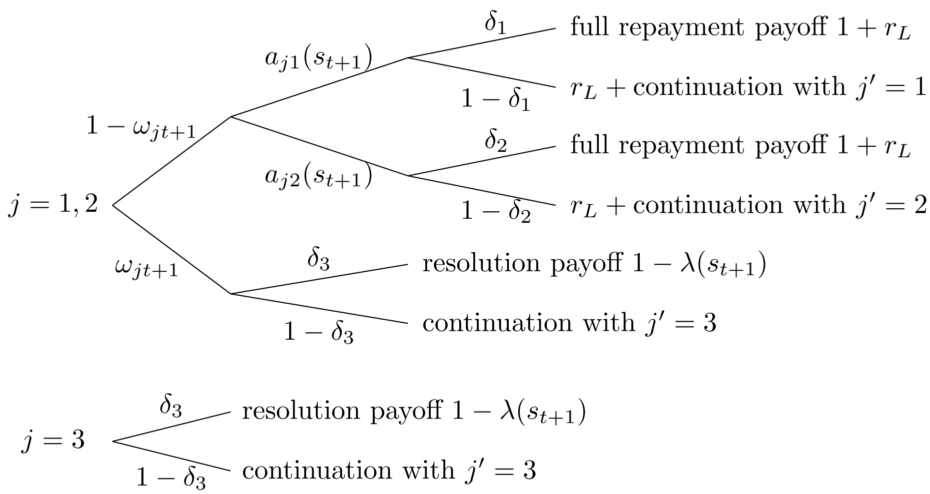
2.1 The bank's loan portfolio

The bank's loan portfolio is composed of a continuum of risky long-term loans which, up to their maturity or resolution after default, feature an identical, constant principal normalized to one and a constant promised interest rate r_L per period. Each individual loan belongs to one of three credit rating categories: standard (j=1), substandard (j=2), or non-performing (j=3). The bank starts each period t with a portfolio of legacy loans described by the column vector $\mathbf{L}_t \equiv [L_{1t}, L_{2t}, L_{3t}]'$ and originates new loans described by the column vector $\mathbf{N}_t \equiv [N_{1t}, N_{2t}, N_{3t}]'$. The components $L_{jt} \geq 0$ and $N_{jt} \geq 0$ of these vectors describe the measure of outstanding and new loans of each category j. Since all loans have a principal of one, the total gross carrying amounts of legacy and new loans in period t are $L_t = \Sigma_{j=1}^3 L_{jt}$, and $N_t = \Sigma_{j=1}^3 N_{jt}$, respectively.

For simplicity, we assume that all newly originated loans are of the standard category, so that $\mathbf{N}_t = [N_t, 0, 0]'$ and we can describe the new loans by just N_t whenever convenient. In originating new loans, the bank incurs an increasing and convex cost $g(N_t)$ on top of the units of lending extended with the new loans.[7]

[7] The convexity of this function helps determine a unique finite optimal amount of newly originated loans per period and so does for the overall size of the bank's loan portfolio. This can be interpreted as a shortcut

Figure 1: Possible transitions of a loan rated j



Note: Possible contingencies between two dates and their implications for the payoffs and continuation of each loan. Variable j describes the state of a loan at t and j' its state at $t+1$ unless the loan reaches maturity or is resolved, in which case the terminal payoffs $1 + r_L$ and $1 - \lambda$, respectively, are realized. Labels above or below each branch describe marginal probabilities conditional on prior events. Conditional on the realizations of s_{t+1} and ω_{jt+1}, all contingencies occur independently across loans so the described probabilities can also be interpreted as proportions of loans of each category for which the corresponding contingencies occur.

Loans evolve across categories, mature or get resolved between dates as described in Figure 1. The top of the figure describes the evolution of the loans that are performing (j=1,2) at t. A fraction ω_{jt+1} of the loans of category j default at $t+1$. The default rates $(\omega_{1t+1}, \omega_{2t+1})$ follow a joint conditional distribution $F(\omega_1, \omega_2; s_{t+1})$ with a mean $(PD_1(s_{t+1}), PD_2(s_{t+1}))$ that can be interpreted as the conditional-on-s_{t+1} probabilities of default of the corresponding loans. Conditional on default, a fraction δ_3 of the loans get resolved within the period, yielding a final payoff $1 - \lambda(s_{t+1})$, where $\lambda(s_{t+1})$ is the realized loss given default (LGD) in state s_{t+1}. The non-resolved fraction $1 - \delta_3$ become part of the legacy non-performing loans (NPLs) of the bank at the next date, L_{3t+1}.

The fraction $1 - \omega_{jt+1}$ of loans of categories j=1,2 at t that do not default remain in or migrate to categories j'=1,2 with probabilities $a_{jj'}(s_{t+1})$, with $\sum_{j'} a_{jj'}(s_{t+1}) = 1$. Finally, a

to having a (partial) equilibrium model with a market demand for loans that is decreasing in the loan interest rate and competition between banks that makes increasingly costly for a bank to increase its loan origination.

fraction $\delta_{j'}$ of the loans ending the period in category j'=1,2 mature, yielding a final payment $1 + r_L$ of principal plus interest, while the remaining fraction pay interest r_L and continue as the legacy loans of the bank at $t + 1$.[8]

The bottom part of Figure 1 describes the evolution of the loans that are non-performing at t (those in category j=3). These loans remain in such an absorbing category, generating no income to the bank, up to their resolution. As in the case of the previously performing loans that default within the period, a proportion δ_3 of the non-performing loans are resolved in every period, yielding a final payoff $1 - \lambda(s_{t+1})$.[9]

Notice that under this formulation, the conditional migration probabilities for outstanding and new loans in t depend on the loan category j in t, the state of the economy at $t + 1$, s_{t+1}, and the realization of ω_{jt+1}. In contrast, the conditional probabilities of maturity or resolution depend on each loan's end-of-period category j'.

From prior descriptions, the law of motion of the legacy loans can be compactly expressed in matrix form as:

$$\mathbf{L}_{t+1} = \mathbf{M}_{t+1}(\mathbf{L}_t + \mathbf{N}_t), \tag{2}$$

where

$$\mathbf{M}_{t+1} = \begin{bmatrix} (1-\omega_{1t+1})a_{11}(s_{t+1})(1-\delta_1) & (1-\omega_{2t+1})a_{21}(s_{t+1})(1-\delta_1) & 0 \\ (1-\omega_{1t+1})a_{12}(s_{t+1})(1-\delta_2) & (1-\omega_{2t+1})a_{22}(s_{t+1})(1-\delta_2) & 0 \\ \omega_{1t+1}(1-\delta_3) & \omega_{2t+1}(1-\delta_3) & (1-\delta_3) \end{bmatrix}. \tag{3}$$

[8]Thus maturity is random and, conditional on remaining in category j', a loan's expected remaining life span is given by $1/\delta_{j'}$. This formulation avoids having to deal with multiple loan vintages. The resulting cash flow stream is very similar to the one that would emerge with a portfolio of perfectly-staggered fixed-maturity loans. Setting $\delta_1 \neq \delta_2$ would allow capturing differences in early redemption probabilities across categories of loans with equal maturity profiles at origination.

[9]The model abstracts from accrued interest while in default as well as the potential return of NPLs to a performing category. In the quantitative analysis, it is possible to roughly account for such interest (as well as possible gains associated with NPL's return to performing categories) by adjusting the loss rate $\lambda(s_{t+1})$.

2.2 Loan loss provisions

Accounting standards establish the recognition of loan loss provisions on both legacy and new loans. We generically represent the corresponding provisions through the following formulas:

$$A_t^L = \boldsymbol{\alpha}(s_t)\mathbf{L}_t, \tag{4}$$

and

$$A_t^N = \boldsymbol{\alpha}(s_t)\mathbf{N}_t, \tag{5}$$

where $\boldsymbol{\alpha}(s_t) \equiv [\alpha_1(s_t), \alpha_2(s_t), \alpha_3(s_t)]$ is a row vector of provisioning coefficients that describe the fraction of the carrying amount of the loans of category j to be recognized as lost in period t.

The specification of $\boldsymbol{\alpha}(s_t)$ differs across accounting standards. We consider three different standards: incurred losses (IL), IFRS 9, and current expected credit losses (CECL), describing them in detail in Section 3.

2.3 Bank equity and its law of motion

To describe the book value of bank equity and its law of motion in the model, it is convenient to distinguish between the equity of the bank before paying dividends and originating new loans, E_t ("pre-dividend equity"), and the equity after those two actions are completed, K_t ("post-dividend equity"). Both are endogenous variables but only enter as a state variable in the bank's recursive optimization problem. To analyze the connection between these variables, we proceed backwards.

After paying its dividends and originating new loans, the balance sheet identity of the bank can be described as

$$(L_t - A_t^L) + (N_t - A_t^N) = D_t + K_t. \tag{6}$$

where the left-hand side reflects the accounting valuation of legacy and new loans net of their provisions, and the right-hand side reflects the sum of the book value of deposits, D_t, and the accounting value of post-dividend equity K_t.

Post-dividend equity is related to pre-dividend equity through the equation

$$K_t = E_t - X_t - A_t^N. \tag{7}$$

which takes into account that both the dividends, X_t, and any provisions associated with the new loans, A_t^N, effectively reduce the equity with which the bank operates in period t.

Finally, assuming that positive profits are taxed at a constant corporate tax rate τ, the law of motion of pre-dividend equity can be described as

$$E_{t+1} = E_t - X_t + (1 - \mathbb{1}_{\{\pi_{t+1}>0\}}\tau)\pi_{t+1}, \tag{8}$$

where π_{t+1} are the pre-tax profits of the bank between periods t and $t+1$. The expression for these profits is:

$$\begin{aligned} \pi_{t+1} =& r_L[(1-\omega_{1t+1})(L_{1t}+N_t) + (1-\omega_{2t+1})L_{2t}] - r_D D_t - g(N_t) \\ & - [\omega_{1t+1}(L_{1t}+N_t) + \omega_{2t+1}L_{2t} + L_{3t}]\,\delta_3\lambda(s_{t+1}) - \Delta A_{t+1}^L. \end{aligned} \tag{9}$$

The first term on the right-hand side represents the interest income of the loans of categories $j \in \{1,2\}$ that remain performing at the end of period t. The second term is the interest paid on the bank's deposits. The third is the cost of originating N_t new loans in period t. The fourth term accounts for the realized losses on defaulted loans that get resolved between periods t and $t+1$, and the last term is the variation in the provisions associated with legacy loans between those periods.[10]

[10] Notice that any newly originated loan at t that remains outstanding at the end of the period is part of the bank's legacy portfolio at $t+1$ and, hence, its provisioning at the end of the period is included in A_{t+1}^L and contributes to the profit or loss of the period via ΔA_{t+1}^L.

2.4 Regulatory capital framework

At the beginning of period t, before new loan origination and dividends distribution take place, the bank faces a regulatory capital requirement specified in terms of pre-dividend equity E_t:

$$E_t \geq \underline{E}_t \equiv \boldsymbol{\gamma}(s_t)\mathbf{L}_t, \tag{10}$$

where the elements $\gamma_j(s_t)$ in the row vector $\boldsymbol{\gamma}(s_t)$ describe the capital required per unit of gross carrying amount of loans rated j. If the bank cannot satisfy this minimum capital requirement, it fails and is resolved by the regulator as further explained below.

In addition to this hard minimum requirement, the regulator also imposes a "soft" requirement on post-dividend equity, $K_t \geq \underline{K}_t$, with the required target given by:

$$\underline{K}_t \equiv (1+\kappa_t)\boldsymbol{\gamma}(s_t)(\mathbf{L}_t + \mathbf{N}_t), \tag{11}$$

where the scalar $\kappa_t \geq 0$ is a regulatory buffer rate which accounts for elements such as those constituting banks CBR under the Basel III regulatory framework. We call this requirement "soft" because it imposes a target that can be missed at the cost of facing constraints on dividends and new lending. Unlike the hard minimum requirement (10), the target in (11) refers to post-dividend equity and takes into account new loans in addition to legacy loans. By using equations (5), (7), and (10), one can check that the requirement $K_t \geq \underline{K}_t$ can be re-written as

$$E_t \geq (1+\kappa_t)\underline{E}_t + \left[(1+\kappa_t)\gamma_1(s_t) + \alpha_1(s_t)\right] N_t + X_t. \tag{12}$$

which, given the non-negativity of all the involved variables and coefficients, would impose on E_t a tighter constraint than the one in (10). However, reflecting the regulatory treatment of the CBR, we assume that if (12) is not satisfied, then the bank must set its decisions on new lending, N_t, and dividends, X_t, in a way that allows E_t to stay as close as possible to $\underline{E}_t$.[11] This means setting $N_t = X_t = 0$ if (12) is not satisfied, which, taking into account that

[11]This captures the "maximum distributable amount" (MDA) restrictions that apply under Basel III when

N_t and X_t are already restricted to be non-negative, can be captured through the following complementary-slackness condition:

$$\Big[E_t - (1+\kappa_t)\underline{E}_t - \left[(1+\kappa_t)\gamma_1(s_t) + \alpha_1(s_t)\right] N_t - X_t\Big](N_t + X_t) \geq 0. \tag{13}$$

2.5 The problem of the bank

Assuming the bank has not yet failed, its state at the beginning of any period t can be fully described by its outstanding loans $\mathbf{L}_t$, its accumulated pre-dividend equity E_t, and the state of the economy s_t. If the bank does not satisfy the minimum capital requirement in (10), the bank is liquidated and its dividend flow becomes zero thereafter. Otherwise, it chooses its non-negative new loans N_t and dividend X_t for period t. In doing so, it is subject to the CBR in (13), which implies setting $N_t = X_t = 0$ unless (12) can be satisfied. In this process, the intermediate variables that describe the capital structure of the bank at t, that is, its deposits D_t and post-dividend equity K_t, are implicitly determined by the balance sheet constraint (6) and the accounting relationship in (7).

Since the objective of the bank is to maximize the value of the stream of dividends paid to its shareholders over time, we can denote such value at the beginning of period t by $V(\mathbf{L}_t, E_t, s_t)$ and describe the optimization problem recursively by the following Bellman equation:

$$\begin{aligned} &V(E_t, \mathbf{L}_t, s_t) \\ &= \begin{cases} \max\limits_{\{X_t \geq 0, N_t \geq 0\}} \left[X_t + \beta \mathbb{E}_t V(E_{t+1}, \mathbf{L}_{t+1}, s_{t+1})\right], \text{ s.t. } (1)\text{-}(9) \ \& \ (13), & \text{if } E_t \geq \underline{E}_t, \\ 0, & \text{if } E_t < \underline{E}_t. \end{cases} \end{aligned} \tag{14}$$

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the CBR is not satisfied.

2.6 Dealing with bank failure

Bank failure, which occurs when $E_t < \underline{E}_t$, is an absorbing state. Having this absorbing state makes it difficult to describe the long-term implications of the model by just averaging over time the variables corresponding to an individual bank, as they stochastically converge to zero. To address this issue, we assume that authorities immediately replace each failing bank with a new bank. Specifically, we assume that the deposit insurance fund takes control of the failing bank, injects some capital to restore its solvency, and sells the refloated bank, which holds the legacy loans of the failed bank, to a new group of shareholders. In this manner, although bank failure is an absorbing state from the perspective of the owners of the bank at a given point in time, we can quantify the long-term implications of the model in terms of lending and other relevant bank-level variables by averaging over time across the endless sequence of operating banks.

For simplicity, since the objective of this paper is not to analyze the implications of alternative bank resolution policies, we just assume that the deposit insurance fund only injects in the failing bank the minimal additional capital that allows it to satisfy the minimum capital requirement in (10). The continuation value and decision problem of the refloted bank is then also given by (14) with the legacy loan portfolio $\mathbf{L}_t$ equal to that of the failed bank and the pre-dividend equity reset at $E_t = \underline{E}_t$.

3 Provisioning standards

This section describes the three loan loss provisioning standards that we compare in the quantitative analysis of the model: IL, IFRS 9, and CECL. The detailed derivation of the closed-form expressions for the provisioning coefficients $\alpha_j(s_t)$ under each of them can be found in Appendix A.

Incurred losses. Under its narrowest interpretation, the IL standard prescribes recognizing the expected losses associated with exposures for which there is clear evidence of impairment, which in our model would be the NPLs in L_{3t} and, if applicable N_{3t}.[12] Thus, provisioning coefficients under the IL approach are

$$\boldsymbol{\alpha}^{\mathrm{IL}}(s_t) \equiv [0, 0, LGD(s_t)], \tag{15}$$

where $LGD(s_t)$ is the *expected* LGD of the defaulted loans conditional on s_t, the state of the economy at the time those expected losses are assessed. Accounting for the random timing of the resolution of the defaulted loans and the variation in the *realized* losses across future states of the economy, the value of $LGD(s)$ for each $s \in S$ can be found by solving the system of equations defined by the following recursive formulas:

$$LGD(s) = \sum_{s' \in S} p_{ss'} \left[\delta_3 \lambda(s') + (1 - \delta_3) LGD(s') \right], \tag{16}$$

for $s \in S$. The formula for each s takes into account that NPLs are resolved by the end of the period with probability δ_3, in which case the realized loss is $\lambda(s')$ where s' denotes the next-date state. Otherwise the NPL remains unresolved and with a (reassessed) expected loss $LGD(s')$ in each of the possible next-date states s'.

IFRS 9. This standard uses a mixed-horizon expected loss approach for performing loans, while maintaining the lifetime expected loss approach for non-performing loans ("stage 3" loans) as in the IL standard. Specifically, it stipulates the recognition of discounted one-year ahead expected losses for exposures that have not suffered a significant increase in credit risk since origination—the "stage 1" loans that we assimilate to loans in our category $j = 1$. Instead, for loans having experienced such a deterioration—the "stage 2" loans that we assimilate to our category $j = 2$—it specifies that the provisions must cover the discounted lifetime expected losses. Additionally, it establishes that the discount rate shall be the contractual loan rate, that is, r_L in our model.

[12] Remember, however, that in the analysis of the model we assume that all new loans belong to category $j = 1$ and thus $N_{3t} = 0$.

Hence, assuming one period in the model is one year, the provisioning coefficients under IFRS 9 can be expressed as

$$\boldsymbol{\alpha}^{\text{IFRS 9}}(s) = [\alpha_1^{1\text{Y}}(s), \alpha_2^{\text{LT}}(s), LGD(s)], \tag{17}$$

where the coefficient for stage 1 loans is just

$$\alpha_1^{1\text{Y}}(s) = \frac{1}{1+r_L} \sum_{s' \in S} p_{ss'} PD_1(s') \left[\delta_3 \lambda(s') + (1-\delta_3) LGD(s')\right], \tag{18}$$

while the coefficient for stage 2 loans can be found by solving the following system of recursive formulas:

$$\begin{aligned} \alpha_j^{\text{LT}}(s) \;&=\; \frac{1}{1+r_L} \sum_{s' \in S} p_{ss'} \Bigg\{ PD_j(s')[\delta_3 \lambda(s') + (1-\delta_3) LGD(s')] \\ &\quad + (1 - PD_j(s')) \sum_{j'=1,2} a_{jj'}(s')(1-\delta_{j'}) \alpha_{j'}^{\text{LT}}(s') \Bigg\}, \end{aligned} \tag{19}$$

for $j \in \{1, 2\}$ and $s \in S$. To explain (18), notice that it just accounts for the possibility that a stage 1 loan defaults between dates t and $t+1$, hence compounding the corresponding transitions of the aggregate state with the implied probabilities of default, the probabilities of being resolved or remaining as NPLs in case of default, and the corresponding realized or expected LGDs.

The recursive formulas in (19), instead, express the provisioning coefficients for loans of each performing category $j \in \{1, 2\}$ as the discounted value of the credit losses per unit of principal that are expected to emerge within one period if the loan defaults (the first term in the curly brackets) plus the reassessed expected value of the lifetime credit losses after one period if the loan does not default. These equations also account for the possible transitions of the aggregate state (from s to s') and migration of the loan across performing categories (from j to j') between dates t and $t+1$.[13]

[13] Notice that after solving the system in (19) only $\alpha_j^{\text{LT}}(s)$ with $j = 2$ will be used to feed $\boldsymbol{\alpha}^{\text{IFRS 9}}(s)$.

Current expected credit losses. Under the CECL standard, all loans are provisioned according to their lifetime expected losses. In the case of NPLs, the provisioning is identical to that under the IL approach. Instead, the future lifetime expected losses of the performing categories $j \in \{1, 2\}$ are discounted using the risk-free rate r (thus differently from IFRS 9, which discounts future losses using the contractual rate r_L). The implied provisioning coefficients can then be represented as

$$\boldsymbol{\alpha}^{\text{CECL}}(s) \equiv [\alpha_1^{\text{CECL}}(s), \alpha_2^{\text{CECL}}(s), LGD(s)], \tag{20}$$

with $\alpha_j^{\text{CECL}}(s)$ for $j \in \{1, 2\}$ given by the following system of recursive formulas:

$$\begin{aligned} \alpha_j^{\text{CECL}}(s) \quad = \quad & \frac{1}{1+r} \sum_{s' \in S} p_{ss'} \Bigg\{ PD_j(s')[\delta_3 \lambda(s') + (1-\delta_3) LGD(s')] \\ & + (1 - PD_j(s')) \sum_{j'=1,2} a_{jj'}(s')(1-\delta_{j'}) \alpha_{j'}^{\text{CECL}}(s') \Bigg\}, \end{aligned} \tag{21}$$

for $j \in \{1, 2\}$ and $s \in S$. These recursive formulas are identical to those in (19) under IFRS 9 except for the discount rate, which here is r rather than r_L.

4 Calibration

We base the quantitative analysis of the model on a calibration intended to represent a typical euro area bank investing in a portfolio of corporate loans around the time of the introduction of IFRS 9, in January 2018. We assimilate a model period to an accounting reporting year and consider the case with just two aggregate states, $S = \{1, 2\}$, that identify whether the economy is in expansion (s_t=1) or contraction (s_t=2) at the beginning of any year t.

4.1 Functional forms and regulatory coefficients

Before explaining how we set all the remaining parameters of the model, we devote this subsection to describe the functional forms and regulatory coefficients required to complete the specification of the model.

Loan origination cost The cost of originating new loans is assumed to be given by

$$g(N_t) = \phi_1 N_t^{\phi_2}, \tag{22}$$

with a scale parameter $\phi_1 > 0$ and an elasticity parameter $\phi_2 > 1$.

Conditional distribution of the default rates We model the conditional-on-s_{t+1} distribution of the default rates $(\omega_{1t+1}, \omega_{2t+1})$ of the loans of categories $j \in \{1, 2\}$ at the end of period t as in Vasicek (2002) single risk-factor model. In such a model, each loan's default depends on both idiosyncratic factors and a common risk factor z_{t+1} which follows a standard normal distribution and explains the correlation in defaults across loans. Consistently with that model, the realization of the default rates can be written as:

$$\omega_{jt+1} = \Phi\left(\frac{\Phi^{-1}(PD_j(s_{t+1})) + \sqrt{\rho} z_{t+1}}{\sqrt{1-\rho}}\right), \tag{23}$$

for $j \in \{1, 2\}$, where z_{t+1} is the $N(0, 1)$ common risk factor, $\Phi(\cdot)$ is the cdf of a standard normal, $\Phi^{-1}(\cdot)$ denotes its inverse, and $\rho \in [0, 1]$ is the so-called correlation parameter, which measures the strength of the dependence of individual loan defaults on the common risk factor.[14] Under this formulation, the conditional mean of the default rate of loans rated j in state s_{t+1} is $PD_j(s_{t+1})$, while the dispersion of the default rate around this conditional mean is increasing in ρ.

Capital requirements The capital requirement coefficients in $\boldsymbol{\gamma}(s_t)$ are specified as in the internal-ratings based (IRB) approach of Basel III. This means using a regulatory formula fed with internal estimates of the PDs and LGDs of the loans. Prudential regulation establishes criteria on how to set these estimates that differ from those relevant for accounting purposes.

[14]See, e.g., Repullo and Suarez (2004) for details. This distribution was used as a statistical foundation for the capital requirement formulas of the IRB approach when first introduced by Basel II (Gordy, 2003).

In particular, instead of best point-in-time estimates of the relevant PDs and LGDs, prudential regulation stipulates the use of "through-the-cycle" (or TTC) PDs and "downturn" LGDs. In our calibration, we assimilate the downturn LGD of all loans to $\lambda(2)$ and the one-year-ahead TTC PDs of the performing loan categories ($j = 1, 2$) to the unconditional mean value $\overline{PD}_j = \sum_{s=1,2} \bar{p}_s PD_j(s)$.[15] Regulatory expected loss coefficients for $j \in \{1, 2, 3\}$ are then given by

$$\overline{\alpha}_j = \lambda(2)\overline{PD}_j, \tag{24}$$

where for NPLs we just have $\overline{PD}_3 = 1$.

Based on the prescription in BCBS (2017, paragraph 53) for corporate loan portfolios under the IRB approach, the regulatory coefficient for loans of category j is determined by

$$\begin{aligned} \gamma_j(s_t) \quad = \quad & \lambda(2) \cdot \Phi\left(\frac{\Phi^{-1}(\overline{PD}_j) + \overline{\mathrm{cor}}_j^{0.5}\Phi^{-1}(0.999)}{(1-\overline{\mathrm{cor}}_j)^{0.5}}\right)\frac{1+\left(\frac{1}{\delta_j}-2.5\right)\overline{m}_j}{1-1.5\overline{m}_j} - \overline{\alpha}_j \\ & + \max\{\overline{\alpha}_j - \alpha_j(s_t), 0\}, \end{aligned} \tag{25}$$

where $\overline{\mathrm{cor}}_j$=0.24–0.12[1–exp(–50$\overline{PD}_j$)]/[1–exp(–50)] is a correlation parameter fixed by the regulator, and $\overline{m}_j = [0.11852–0.05478\ln(\overline{PD}_j)]^2$ is the maturity adjustment parameter also fixed by the regulator. In this formula, the first term represents the regulatory measure of the 99.9 percentile of the credit losses (per unit of gross carrying amount) of loans of category j, the second term subtracts the regulatory measure of the expected losses, and the third term introduces an adjustment (or "regulatory filter") for the case in which those regulatory expected losses exceed the provisions implied by the prevailing accounting standard.[16]

[15] Regulators recommend using TTC PDs to avoid the cyclicality of the $\gamma_j(s_t)$ coefficients. The alternative point-in-time (PIT) approach would involve using $\overline{PD}_j(s_t) = \sum_{s'} p_{s_t s'} PD_j(s')$ instead of $\overline{PD}_j$ and $LGD(s_t)$ instead of $\lambda(2)$.

[16] On top of this, when the difference $\overline{\alpha}_j - \alpha_j(s_{t+1})$ is negative, Basel III allows the bank to add back $\alpha_j(s_{t+1}) - \overline{\alpha}_j$ (up to a regulatory maximum) to its Tier 2 capital. To simplify the analysis, we abstract from such an adjustment as well as the distinction between Tier 1 and Tier 2 capital. This is equivalent to assuming that the bank must satisfy both its minimum capital requirement in (10) and its CBR in (11) with common equity (in regulatory jargon, CET1).

Combined buffer requirement In the baseline calibration, we assume the regulatory capital buffer κ_t to be constant at $\kappa = 0.3125$ so as to reproduce the target size of the capital conservation buffer in Basel III, which is set equal to 2.5% of risk weighted assets (RWAs).[17] In Section 6.2 we consider an extension capturing the introduction of a countercyclical capital buffer, in which κ_t is time-varying.

4.2 Parameter values

Table 1 describes the values of all the model parameters and the data sources and/or targets behind them. The first block contains general parameters that do not vary with the cyclical position of the economy. The second block contains the parameters that determine the evolution of loans' credit risk, some of which vary across expansion and contraction states.

General parameters The risk-free rate r is set to 2%, matching the 3-month Euribor rate in the euro area as in Mendicino et al. (forthcoming). Consistent with our assumption that deposits are fully insured, the deposit rate r_D is also set equal to 2%. The loan rate r_L is set to 4%, implying an interest margin of 2%, consistent with the average intermediation margin observed for euro area banks in the calibration period.[18] The corporate tax rate τ is set at 20%, which is the average effective tax rate for European banks reported in Aswath Damodaran's dataset.[19] The transition probabilities of the aggregate state are set to match the average durations of the phases of expansion (6.7 years) and contraction (2 years) in the data that we use to attribute cyclicality to the credit risk parameters (see Appendix B for details).

The shareholders' discount factor β and the correlation parameter ρ that enters (23) (and determines the volatility of the loan default rate) are set simultaneously so as to match the average return on equity and the unconditional probability of bank failure, as shown in Table

[17] Regulatory RWAs equal 12.5 (or 1/0.08) times the bank's minimum required capital $\underline{E}_t$. Thus a buffer requirement of 2.5% amounts to a multiple $0.025 \times 12.5 = 0.3125$ of $\underline{E}_t$.

[18] This setting of r_L neutralizes the implications for bank profitability of not explicitly considering market power in the setting of the deposit rate.

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

Table 1: Calibration of the model: Parameter values

General parameters			Source/target
Risk-free rate	r	2%	3-month Euribor rate
Loan rate	r_L	4%	Net interest margin
Deposit rate	r_D	2%	Risk-free rate
Corporate tax rate	τ	20%	Damodaran database
Persistence of the expansion state (s=1)	p_{11}	85%	Avg. expansion length
Persistence of the contraction state (s=2)	p_{22}	50%	Avg. recession length
Loan origination cost - scale parameter	ϕ_1	0.1	Normalization
Loan origination cost - elasticity parameter	ϕ_2	4.5	Volatility of new loans' growth
Bank shareholders' discount factor	β	0.925	Avg. return on equity
Single risk factor correlation parameter	ρ	0.38	Avg. prob. of bank failure
Combined buffer requirement coefficient	κ	0.3125	Capital conservation buffer

Credit risk parameters		Boom	Bust	Source/target
Probability of migration 1 → 2	a_{12}	5.80%	10.86%	Own elaboration based on S&P Global Corporate Default reports; see Appendix B for details
Probability of migration 2 → 1	a_{21}	7.27%	5.06%	
Avg. probability of default if rated j=1	PD_1	0.51%	1.80%	
Avg. probability of default if rated j=2	PD_2	6.01%	11.46%	
Loss given default	λ	30%	40%	Brumma & Winckle (2017)
Avg. time to maturity if rated j=1	$1/\delta_1$	5 years	5 years	Cortina et al. (2018)
Avg. time to maturity if rated j=2	$1/\delta_2$	5 years	5 years	Cortina et al. (2018)
Avg. time to resolution if rated j=3	$1/\delta_3$	3.3 years	3.3 years	Average share of NPLs

Note: For brevity, "Boom" means expansion states (s=1) and "Bust" means contraction states (s=2).

2. Parameter ϕ_1 in the loan origination cost function is a pure scale parameter, and thus we fix it so as to normalize the average size of the total loans under the IL standard to a reference value of 100. Finally, we set the elasticity parameter ϕ_2 to match the volatility of the growth rate of aggregate new corporate loans in the data.[20]

[20] We compute the model counterpart of aggregate new corporate loans by averaging across 10,000 simulated time series trajectories with the same sequence of aggregate states s_t but independent draws of the single risk factor z_t that, according to (23), determines the realizations of the default rates ω_{jt} for $j \in \{1, 2\}$ in each period. This implies treating such a risk factor as a bank-idiosyncratic factor and the aggregate variable as the one corresponding to aggregating over a large number of (heterogeneously performing) banks.

Table 2: Targeted moments: Model vs. data

Moments		Data	Model
Average return on equity	$(1-\mathbb{1}_{\{\pi_t>0\}}\tau)\pi_t/K_{t-1}$	7.99%	8.16%
Average probability of bank failure	$\text{Prob}(E_{t+1}<\underline{E}_{t+1})$	0.66%	0.74%
Average share of NPLs	$L_{3t}/(L_t+N_t)$	4.32%	4.70%
Volatility of new loans' growth rate	$\text{vol}(N_t/N_{t-1}-1)$	9.64%	9.95%

Credit risk parameters Given the absence of detailed publicly available information on the credit quality composition and cyclical evolution of European corporate loans, the calibration of this block relies on combining rating migration and default probabilities consistent with the Global Corporate Default reports produced by Standard & Poor's (S&P) over the period 1981-2017 and aggregate variables taken from statistics of the European Central Bank.[21]

As explained in Appendix B, we assign state-contingent PDs and probabilities of migration across our performing loan categories by assimilating standard loans (j=1) with bonds in ratings AAA to BB in the S&P classification, and substandard loans (j=2) with bonds in ratings B to C.[22] To reduce the 7×7 rating-migration probabilities and the seven PDs taken from S&P data to the 2×2 migration probabilities and two probabilities of default per aggregate state in our model, we calculate weighted averages of the S&P categories that take into account the composition of the hypothetical asymptotic fixed-composition portfolio that would arise with no movements in the aggregate state s and a constant inflow of new loans. Once we obtain the weights of the original S&P categories that define each of our performing loan categories, we assign cyclical variability to the corresponding rating migration rates and default rates by extrapolating the (weighted average) cyclical variation observed in the S&P data.

As shown in Table 1, expansions feature significantly smaller PDs among both standard

[21] We use reports equivalent to Standard & Poor's (2016) published between years 2003 and 2018, which provide the relevant information for each of the years between 1981 and 2017.

[22] We choose the mapping between our categories and S&P classification so as to minimize the distance between the unconditional loan default rate in our model and its counterpart in the data.

and substandard loans than contractions. During a contraction, the probability of standard loans being downgraded (and, under IFRS 9, moved into stage 2) is almost twice as that during an expansion. The probability of substandard loans recovering standard quality (or returning to stage 1) during a contraction is reduced by about one-third relative to that during an expansion. The unconditional average yearly PDs for our standard and substandard categories are 0.81% and 7.3%, respectively. Conditional on being in an expansion and in a contraction, the average annual loan default rates for performing loans are 1.3% and 3.4%, respectively.

Consistently with the cyclical evolution of average realized LGDs on European unsecured loans to large non-financial corporations reported by Brumma and Winckle (2017, Exhibit 3), the loss rate $\lambda(s)$ experienced when defaulted loans get resolved is set equal to 40% during contractions and 30% during expansions.[23]

To reduce the sources of cyclical variation in the results to those that have been best documented in prior literature, we make the parameters determining the effective maturity of performing loans and the speed of resolution of NPLs equal across states. We set $\delta_1 = \delta_2 = 0.2$, which implies an average loan maturity, absent default, of 5 years, identical for standard and substandard loans. This maturity is consistent with the weighted average maturity reported in Cortina, Didier, and Schmukler (2018) for syndicated loans in developed economies over the period 1991-2014. Finally, we fix δ_3 to match an average share of NPLs for euro area banks of around 4%.[24]

[23] An LGD of 40% in contractions is also consistent with the (downturn) LGD prescribed by BCBS (2017, paragraph 70) for unsecured corporate loans under the foundation IRB approach. Our numbers are also consistent with the cyclical variation in loss rates documented by Bruche and González-Aguado (2010) for defaulted senior unsecured corporate bonds.

[24] This number is consistent with the time series average for years 1990-2015 in the World Bank Global Financial Development Database.

5 Quantitative results

This section presents the main results of the paper. We first study how loan loss provisions and capital requirements vary across alternative provisioning standards, with a focus on differences in their cyclicality (Section 5.1). We then consider the implications for endogenous variables such as new loans, total loans, dividends, and bank failure rates (Section 5.2). Lastly, we analyze the dynamic responses to the arrival of a contraction (Section 5.3).

5.1 Provisioning and capital needs

Table 3 describes provisioning coefficients, provisions as a share of total loans, capital requirement coefficients, and equity needs per unit of total loans as well as the loan portfolio composition implied by our calibrated model. We report the conditional means of the listed variables in expansions (denoted "booms", for brevity) and contractions (denoted "busts"), and, as a summary measure of cyclicality, the difference between the bust and the boom means (denoted as "Diff." in the table). The columns are organized in three blocks, covering of the three provisioning standards that we compare: IL, IFRS 9, and CECL.

The rows in the table are organized in five blocks. The first block shows the cyclical variation in the composition of the loan portfolio. Relative to expansions, contractions imply an average fall of around 7.5 pp in the share of standard loans, an increase of around 4.7 pp in the share of substandard loans and a rise of around 2.7 pp in the share of NPLs. The loan composition and its cyclicality are similar across provisioning standards since they are mainly driven by probabilities of migration across loan categories, which do not change with the standards.

The second block of the table reflects that under the IL standard, provisioning coefficients $\alpha_j(s)$ are only positive for NPLs (and with limited cyclical variation since the state-contingency of realized LGDs is averaged out by the possibility of state switching before the NPLs get resolved). IFRS 9 and CECL involve identical provisioning coefficients for NPLs as IL, but strictly positive ones for standard and substandard loans. The provisioning rates for substandard loans are similar under both forward-looking standards since both of them pre-

Table 3: Provisions and required capital across accounting standards

	IL			IFRS 9			CECL		
	Boom	Bust	Diff.	Boom	Bust	Diff.	Boom	Bust	Diff.
Share of standard loans	81.7	74.3	-7.4	81.7	74.2	-7.5	81.8	74.0	-7.8
Share of substandard loans	14.2	18.9	4.7	14.2	19.0	4.8	14.2	19.3	5.1
Share of NPLs	4.1	6.8	2.7	4.0	6.8	2.7	4.0	6.8	2.8
Provisioning coefficients*									
Standard loans	0.0	0.0	0.0	0.2	0.4	0.2	2.5	2.9	0.3
Substandard loans	0.0	0.0	0.0	7.0	7.8	0.9	7.4	8.3	0.9
NPLs	32.0	33.4	1.4	32.0	33.4	1.4	32.0	33.4	1.4
Loan loss provisions	1.3	2.3	1.0	2.5	4.1	1.6	4.4	6.0	1.6
Standard loans	0.0	0.0	0.0	0.2	0.3	0.1	2.1	2.1	0.1
Substandard loans	0.0	0.0	0.0	1.0	1.5	0.5	1.1	1.6	0.5
NPLs	1.3	2.3	1.0	1.3	2.3	1.0	1.3	2.3	1.0
Capital requirement coefficients*									
Standard loans	8.8	8.8	0.0	8.5	8.4	-0.1	8.4	8.4	0.0
Substandard loans	17.2	17.2	0.0	14.3	14.3	0.0	14.3	14.3	0.0
NPLs	8.0	6.6	-1.4	8.0	6.6	-1.4	8.0	6.6	-1.4
Minimum capital requirement	9.9	10.2	0.3	9.3	9.4	0.1	9.2	9.4	0.2
Combined buffer requirement	13.0	13.4	0.4	12.2	12.4	0.1	12.1	12.4	0.3
Capital needs = CBR + provisions	14.3	15.7	1.3	14.7	16.4	1.7	16.5	18.4	1.8

Note: All numbers represent percentages over total gross loans, except for provisioning and capital requirement coefficients (indicated with *), which represent percentages over loans in each of the corresponding categories.

scribe recognizing discounted lifetime expected losses and the differences arising from their contrasting discounting conventions are small—only adding a few extra basis points (bp) to the provisioning rates under CECL. For standard loans, the difference in provisioning rates across IFRS 9 and CECL is more significant, since for stage 1 loans IFRS 9 only takes into account one-year expected losses, while CECL does not distinguish between stages and considers lifetime expected losses for all loans. This makes the CECL provisioning coefficients for $j = 1$ loans more than 2 pp higher than their IFRS 9 counterpart in either of the cyclical states. Since standard loans account for about 80 percent of the total loans, these differences have important implications for other endogenous variables, as shown below.

This is the case for the total provisioning needs per unit of gross loans, as well as their cyclical variation, which are shown in the third block of Table 3. Under CECL, these needs more than triple in booms and more than double in busts relative to IL, while in the case of IFRS 9, they almost double in both states. In terms of the cyclical variation in overall provisioning needs, CECL and IFRS 9 end up being very similar, with "Diff." being about 1.6 pp of total gross loans (compared with 1 pp under IL). It is worth noting that IFRS 9 brings the extra cyclicality mainly through the cliff effect caused by the larger migration of loans from stage 1 to stage 2. In the case of CECL such a cliff effect is smaller because all loans are provisioned on a lifetime basis since origination. However, the higher provisions for standard loans in busts (also due to the lifetime approach) offset the previous difference, making IFRS 9 and CECL eventually very similar in terms of the cyclicality of total provisions.

The fourth block in Table 3 shows the capital requirement coefficients $\gamma_j(s)$ for each loan category. These differ across provisioning regimes due to the existence of prudential adjustments (the third term in equation (25)) reflecting the potentially positive discrepancy between the regulatory definition of expected loss and the loan loss provisioning rates. These adjustments make capital requirements larger when the difference is positive, which is the case mostly for performing loans provisioned under the IL standard. This explains why, relative to IL, the capital requirement under IFRS 9 and CECL is around 0.3 pp lower for standard loans, and almost 3 pp lower for substandard loans. In contrast, the capital requirements for NPLs do not vary across accounting standards, since in this case the three standards use the same provisioning coefficients. Eventually, the cyclical difference in capital charges on performing lonas is minor under the three standards, while the capital charge on NPLs (identical under the three standards) is smaller in busts than in booms.

The last block in Table 3 describes the overall capital needs per unit of loans under each accounting standard. The differences due to the above-mentioned prudential adjustments translate into overall minimum capital requirements (and CBRs) that are at least 0.6 pp (and 0.8 pp, respectively) higher under IL than under the two forward-looking provisioning standards. These effects, however, do not fully offset the positive impact of these standards on the overall equity funding that the bank needs to sustain its lending activity. This is especially the case under CECL, where the difference with respect to the IL regime exceeds 2 pp in both aggregate states.

Along the cyclical dimension, the effect of provisions on the overall capital needs per unit of lending also dominate. As shown in the bottom row of Table 3, the equity needed to cover the sum of provisions and the CBR in booms goes from about 14.3 pp under IL to about 14.7 pp under IFRS 9 and above 16.5 pp under CECL. In busts, the equity need goes from 15.7 pp under IL to 16.4 pp under IFRS 9 and 18.4 pp under CECL. As a result of this, the average cyclical variation of the equity capital needed to support bank lending increases with the new standards: from the 1.3 extra pp of capital in busts under IL to the 1.7 and 1.8 extra pp under IFRS 9 and CECL, respectively.

5.2 Profitability, capital-availability, and lending

Table 4 reports unconditional means, state-contingent means, and differences between the means in expansions and contractions for a broad set of endogenous variables describing the behavior of the bank under each of the compared provisioning standards. Its first block imports from the last row of Table 3 the overall capital needs per unit of gross loans implied by the provisions and capital requirements under each standard. The unconditional capital needs under IFRS 9 are only 0.50 pp higher than under IL while the needs under CECL are 2.30 pp larger than under IL. This mainly reflects, as already described above, the greater provisions that CECL implies for standard loans. The overall capital needs per unit of lending are a key determinant of the profitability of loan origination under each standard.

Reflecting the differences in those needs and relative to IL, the second block of Table 4 shows that the average total loans are only 0.9% smaller under IFRS 9, while they are 13.5% smaller under CECL. By reducing loan origination, the bank offsets the rise in the funding cost of new loans with a reduction in the marginal loan-origination costs.[25] The smaller flow of new loans explains the significantly lower average amount of total loans under CECL compared with IL or IFRS 9.

[25]This mechanism is isomorphic to the one that would operate if the bank were facing a (local) demand for new loans which were downward slopping in some loan origination fees decided by the bank. In such a setup, the bank could react to the rise in its funding costs by increasing the origination fees (a form of loan repricing), which would shrink the demand for new loans and hence the implied level of N_t, like in the current formulation.

Table 4: Endogenous variables across provisioning regimes

	IL				IFRS 9				CECL			
	Avg.	Boom	Bust	Diff.	Avg.	Boom	Bust	Diff.	Avg.	Boom	Bust	Diff.
Capital needs	14.6	14.3	15.7	1.3	15.1	14.7	16.4	1.7	16.9	16.5	18.4	1.8
New loans*	20.6	21.7	17.0	-22.7	20.4	21.6	16.6	-24.5	17.8	19.1	13.5	-27.6
Total loans*	100.0	101.6	94.7	-6.9	99.1	100.8	93.5	-7.4	86.5	88.4	80.2	-9.4
New/Total loans	20.5	21.4	17.6	-3.8	20.5	21.5	17.4	-4.1	20.5	21.7	16.6	-5.1
Loan default rate	1.9	1.4	3.6	2.2	1.9	1.4	3.6	2.2	1.9	1.4	3.6	2.2
Dividend yield	8.0	8.8	5.4	-3.5	8.7	9.7	5.3	-4.5	9.2	9.9	6.8	-3.1
Capital headroom	4.3	4.6	3.3	-1.3	4.3	4.6	3.2	-1.5	4.9	5.3	3.8	-1.5
Prob(dividend=0)	9.9	6.4	21.7	15.3	9.0	5.4	21.2	15.8	7.7	4.8	17.5	12.7
Prob(headroom<0)	2.3	0.7	7.6	6.9	2.2	0.6	7.4	6.8	1.5	0.4	5.3	4.9
Bank failure rate	0.7	0.2	2.5	2.3	0.7	0.2	2.6	2.4	0.5	0.1	1.9	1.8

Note: All numbers represent percentages except for "New loans" and "Total loans" (indicated with *), whose unconditional and state contingent means are reported in levels (to be compared with the unconditional mean total loans under IL provisions, which is normalized to 100); the mean bust-boom difference ("Diff.") for these variables is reported as a percentage of the corresponding unconditional mean.

This block of the table also shows that the forward-looking provisions of IFRS 9 and CECL increase the cyclicality of bank lending relative to the backward-looking provisions of IL. This is reflected in the variation across boom and bust states of both new and total loans, as well as the share of new loans in total loans. The bust-boom differences in total loans (as a percentage of the corresponding unconditional mean) are -6.9%, -7.4%, and -9.4% under IL, IFRS 9, and CECL, respectively. So, relative to IL, IFRS 9 and CECL add 0.5 and 2.5 pp, respectively, to the average cyclical variability in total lending.

The forces behind the average cyclical variation in lending under each provisioning regime include a *profitability effect* (originating loans is less profitable when default rates are higher and lending involves higher capital needs) and a *capital-availability effect* (banks experiencing or having experienced higher default rates on past lending may not have the capital headroom necessary to sustain their desired amount of new loans).[26] The first effect explains the cyclical contraction in lending even in situations where the bank is paying dividends and, hence, evidencing not to be constrained by the availability of capital. The second effect operates in its most radical manner when the bank fails and less radically when it is able to comply

[26] We define the capital headroom (per unit of total loans) as the difference between the pre-dividend equity E_t with which the bank enters a given period t and the equity that it would need to comply with the CBR before taking its new lending and dividend payout decisions, $(1+\kappa_t)\underline{E}_t$.

with the minimum capital requirement but not the CBR, as well as when complying with the latter requires making dividends equal to zero and reducing new lending beyond what the profitability effect would call for. The frequency with which the bank ends up in each of these situations can be seen in the rows labeled "Bank failure rate," "Prob(headroom<0)," and "Prob(dividend=0)" in the third block of Table 4.

The variables that measure capital-availability issues take lower values under CECL than under both IL and IFRS 9. This suggests that the higher effective capitalization of banks under CECL mitigates the capital-availability effect and makes the profitability effect the main driver of both the average contraction in lending and the rise in the cyclicality of lending relative to the other two standards. In the case of IFRS 9, the profitability effect is weaker than under CECL, but the capital-availability effect makes a stronger contribution to the cyclicality of credit than under both IL and CECL. Specifically, IFRS 9 is the provisioning regime exhibiting the largest cyclical variation in both dividend yields and the probability that dividends have to be canceled by force of the CBR. This suggests a higher prevalence of capital scarcity problems during contractions with this standard.

Importantly, the greater capital availability issues associated with IFRS 9 have contractive effects on credit supply during busts but do not imply a greater probability of bank failure than under IL. Along this dimension, IL and IFRS 9 are virtually identical both unconditionally and conditionally on each cyclical state. In contrast, the higher effective capitalization reached under CECL makes banks significantly less likely to fail under such a standard.

To further disentangle the impact of the profitability and capital-availability effects on credit supply, the top-row panels in Figure 2 describe the relationship between pre-dividend capital per unit of gross legacy loans (E_t/L_t) and new lending (N_t) that emerges from simulating the model over a large number of paths. It provides the scatter plot of $(E_t/L_t, N_t)$ pairs reached after being in the expansion state in period $t-1$ in two different situations: (i) when in period t the economy remains in expansion ($s_t = 1$, blue circles), and (ii) when in period t the economy enters a contraction ($s_t = 2$, red crosses). Each panel corresponds to a different provisioning standard.

The variation in the horizontal axis describes the availability of pre-dividend equity in comparison to the volume of legacy loans. When the ratio $(E_t/L_t, N_t)$ is high enough, the bank is unconstrained, and its loan origination is maximum at some equity-independent level. This corresponds to situations in which the bank can pay a positive dividend to its shareholders. At the opposite extreme, when $(E_t/L_t, N_t)$ is too low, either the bank violates the minimum capital requirement and fails or it needs to reduce its new lending (as well as its dividends) to zero to comply with the prescription of the CBR. Only in the intermediate range, changes in the availability of pre-dividend equity translate, linearly, into changes in new lending.

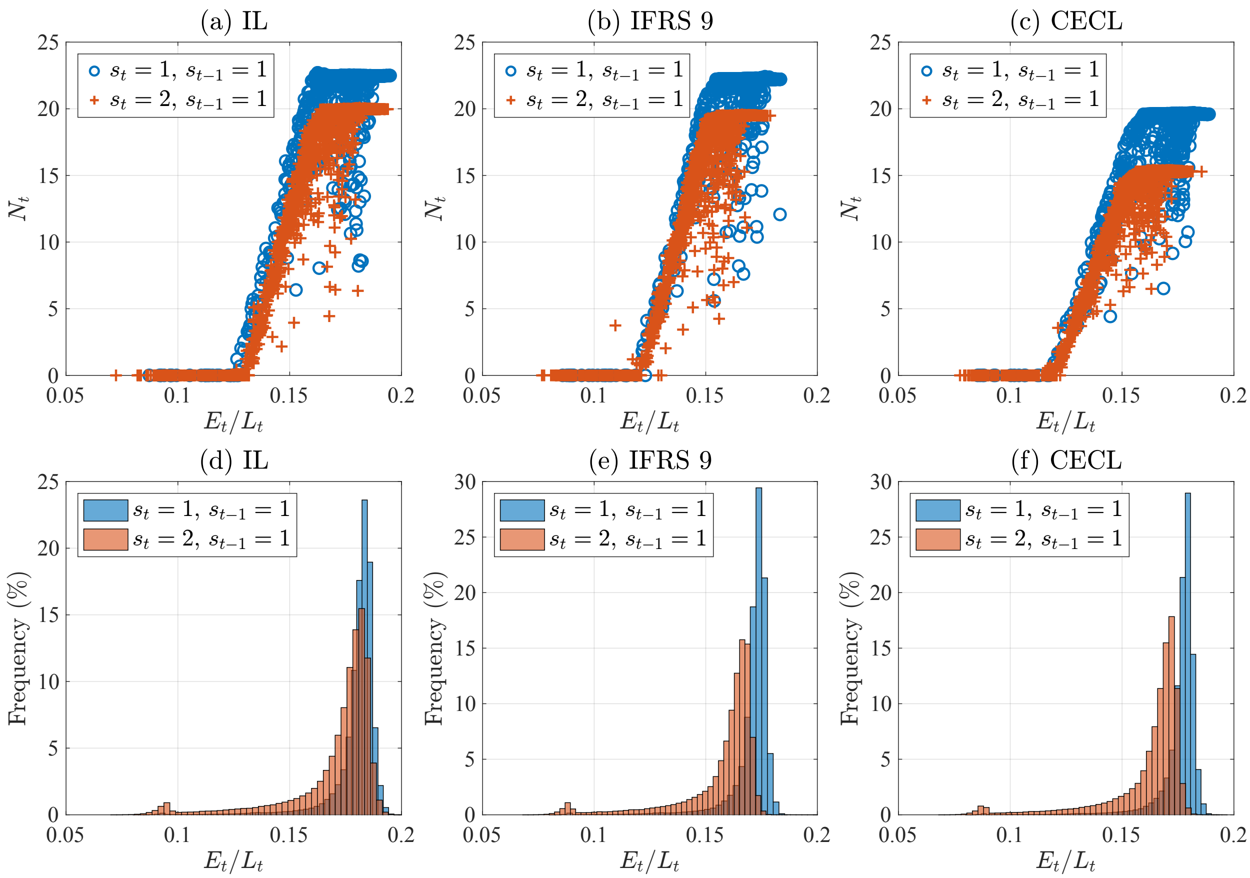
The panels in the top row of Figure 2 illustrate the differences in the unconstrained optimal level of lending across states and provisioning regimes, with CECL being the one under which banks wish to originate fewer new loans and where the difference across states is the largest. The panels in the bottom row illustrate how the forward-looking features of IFRS 9 and CECL exacerbate the cyclical differences in capital availability, shifting the densities of the variable E_t/L_t in the contraction state further down relative to those in the expansion state. However, under CECL, the vast majority of E_t/L_t realizations in contraction periods still fall within the range where new lending is unconstrained. With IRFS 9, consistently with the higher value of the indicators shown in the third block of Table 3, more of those realizations fall in the range where the lack of capital linearly translates into less new lending.

Taken altogether, these results suggest that the more forward-looking provisioning standards of CECL and IFRS 9 share in common their procyclical impact on loan origination relative to IL, but have very different implications across other important dimensions such as the incidence of the capital-availability effect, and the final impacts on total lending, dividend policy, and bank solvency.

5.3 Effects of the arrival of a contraction

To further dig into the dynamic effects of the alternative provisioning standards, we now study the behavior and performance of the bank upon the arrival of a contraction after being for sufficiently many periods in the expansion state. Figure 3 shows the results, in which the

Figure 2: Bank capitalization and new lending across provisioning standards

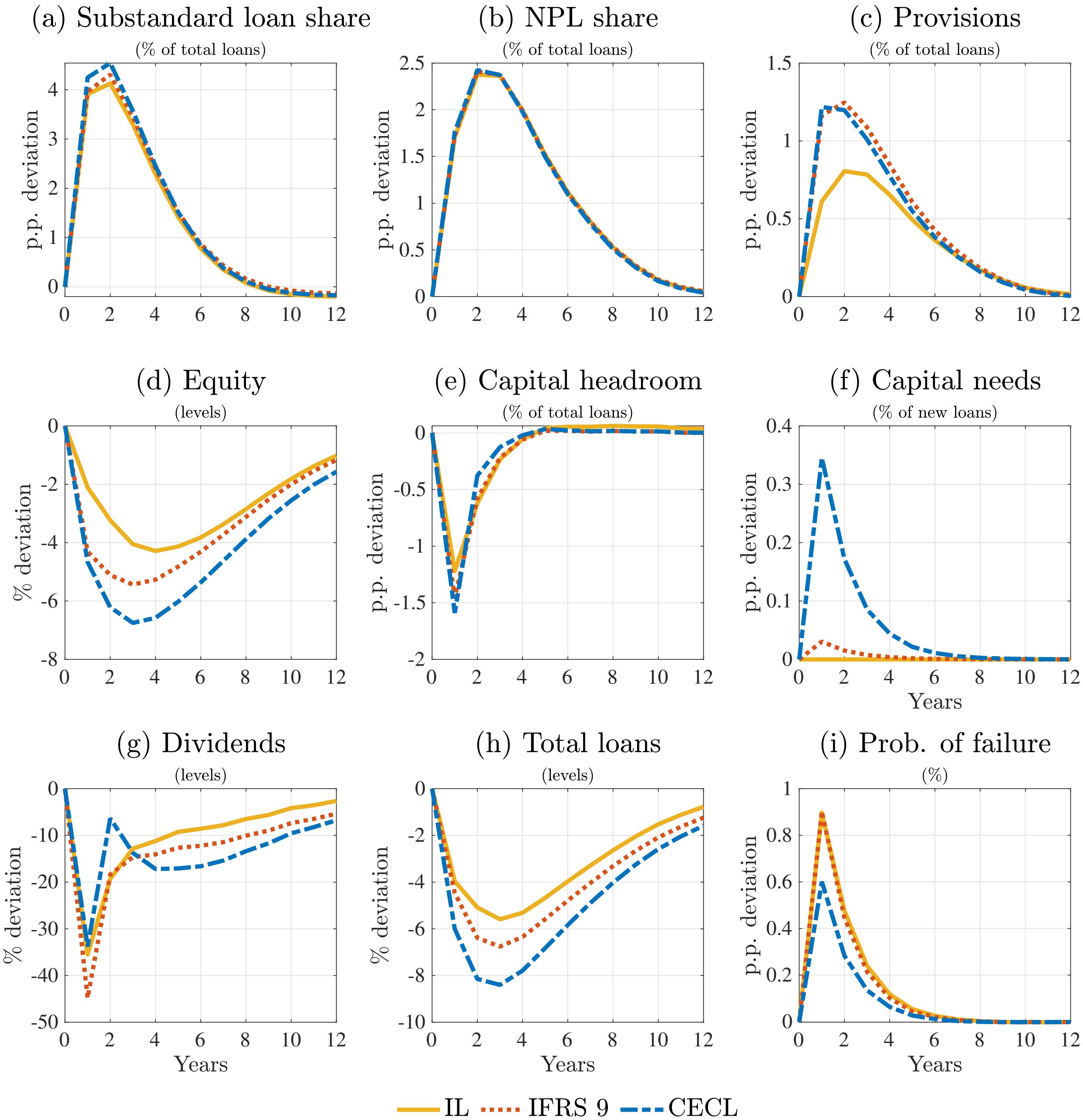


Notes: Panels (a)-(c) depict the relationship between pre-dividend equity per unit of gross legacy loans (E_t/L_t,; horizontal axis) and new loan origination (N_t, vertical axis), with a different provisioning standard in each panel. Blue circles (red crosses) represent observations in which the economy is in an expansion (contraction) following a period of expansion. Panels (d)-(f) depict the frequency with which E_t/L_t takes different values in the ergodic distribution of the simulated model. Blue (red) bars represent observations in which the economy is in an expansion (contraction) following a period of expansion.

contraction arrives in $t = 1$ and from $t = 2$ onwards the aggregate state evolves according to the calibrated Markov chain. The figure depicts the average trajectories resulting from simulating 10,000 paths.

Panels (a) and (b) show the trajectories of the shares of substandard and non-performing loans in total loans, which are very similar in the three provisioning regimes. Despite the relatively short duration of the contraction state (2 years on average), the increases in the shares of substandard loans and NPLs are quite persistent, remaining at above-normal levels

Figure 3: Effects of the arrival of a contraction



Notes: Average response to the arrival of a contraction at $t = 1$. The variables depicted in each panel are defined as follows: (a) Substandard loan share = $L_{2t}/(L_t+N_t)$; (b) NPL share = $L_{3t}/(L_t+N_t)$; (c) Provisions = $A_t/(L_t+N_t)$; (d) Equity = K_t; (e) Capital headroom = $[E_t-(1+\kappa_t)\underline{E}_t]/L_t$; (f) Capital needs = $\alpha_1(s_t)+(1+\kappa_t)\gamma_1(s_t)$; (g) Dividends = X_t; (h) Total loans = L_t+N_t; (i) Prob. of failure: Prob$(E_{t+1} < \underline{E}_{t+1})$.

for up to 8 years after the onset of the contraction.

Panel (c) reports the average trajectories of loan loss provisions as a percentage of total loans. They all show a hump shape but with significant differences across IL and the forward-looking regimes. Under the latter, provisions peak earlier (in the first year), reach higher levels, and remain higher for longer than under the former (where the peak is reached in the second year).[27] Importantly, in period $t = 1$, the average increase in provisions under IL is (as a percentage of its initial level) only half of those under IFRS 9 and CECL, implying a smaller negative impact on lending profitability and capital availability in that period.

Each regime spreads credit losses over time in a different manner. Under IFRS 9 and CECL, bank profits fall sharply on impact, but then recover pretty quickly afterwards. Under IL, profits initially fall less than under the other regimes, but then they remain lower for longer. These different responses largely explain the evolution of pre-dividend equity shown in panel (d) as well as the capital headroom shown in panel (e). Clearly, the forward-looking provisioning approaches imply stronger declines in capital availability than the IL approach.

Panel (f) describes the variation in the capital needed to support the provisions and regulatory capital requirements associated with the new loans. These capital needs affect the profitability of new lending and interact with the bank's capital headroom to determine whether it can originate as many new loans as it would find profitable to do. As previously discussed, the rise in these needs following the arrival of a contraction is significantly more pronounced under CECL than the two other standards.

The differential impacts of the three provisioning regimes on the previously mentioned variables explain the trajectories of dividends and total loans depicted in panels (g) and (h), respectively. Specifically, the trajectory of dividends evidences that IFRS 9 implies a relatively stronger capital-availability effect (that is, a larger probability that banks are capital-constrained and react by canceling their dividends) than CECL, and also confirms that the reason behind the greater fall in loan origination and, consequently, total loans under

[27]Recognizing credit losses only once loans are impaired makes the loss recognition closer in time to the resolution of the corresponding loans and, hence, implies a lower average level of provisions over a loan's life-cycle (even if the latent credit losses are exactly the same under all provisioning regimes).

CECL is the profitability effect.[28]

Panel (i) completes the description of the responses to the arrival of a contraction showing the average trajectory of the probability of bank failure. This average probability increases on impact by around 90 bp under IL and IFRS 9, and by 60 bp under CECL, before gradually falling back to normal levels. Thus IFRS 9 essentially implies no change in bank solvency relative to IL, while CECL emerges as the regime that better preserves bank solvency during contractions (albeit, as previously shown, at the cost of a larger contraction in lending on average and during contractions).

6 Effectiveness of the CCyB in countering cyclicality

This section studies the effectiveness of the CCyB of Basel III under each of the provisioning standards compared in previous sections. In recent years, macroprudential policy discussions and practices have consolidated the CCyB as the main capital-based macroprudential tool of the current regulatory framework, and taken many policymakers to concur on the convenience of having a "positive neutral" CCyB rate (Basel Committee on Banking Supervision, 2024). The idea is that having this buffer activated at a strictly positive level during non-contractionary phases of the business or financial cycle will allow authorities to react to the arrival of a downturn with its release, mitigating the potential credit-reducing effects of the scarcity of bank capital during downturns.

6.1 Adding a neutral CCyB rate to the CBR

Reflecting the terms of the policy debate, we first consider (in this subsection) the impact of introducing a positive neutral CCyB rate of 1% (of RWAs) which, after sufficiently many periods in the expansion state, adds to the 2.5% rate of the CBR in our baseline results, making it up to 3.5% in total. The neutral rate in this first policy counterfactual is gradually

[28] Notice that under CECL average dividends fall at $t = 1$ but then overshoot at $t = 2$, as unconstrained banks find it optimal to originate fewer-than-normal new loans until the arrival of the expansion state.

added in the form of 50 bp per year starting in the second year after a contractionary phase is over, and until the 100 bp neutral rate is reached (or a new contraction arrives).[29] Whenever a contraction arrives, the CCyB rate becomes zero and remains so until the contraction phase is over a new activation process starts.

As a second policy exercise (in the next subsection), we consider the alternative design, often referrred as "capital neutral," in which the new CCyB policy is combined with a permanent reduction of 1% in the baseline level of the CBR. In each exercise we evaluate how the level and cyclicality of credit supply and of bank solvency get affected relative to the baseline scenario without a CCyB policy.

To capture the dependency on the CCyB policy on the number of years since the last contractionary period, we introduce a new variable τ_t defined as follows:

$$\tau_t = \begin{cases} \tau_{t-1} + 1, & \text{if } s_t = 1, \\ 0, & \text{if } s_t = 2, \end{cases} \tag{26}$$

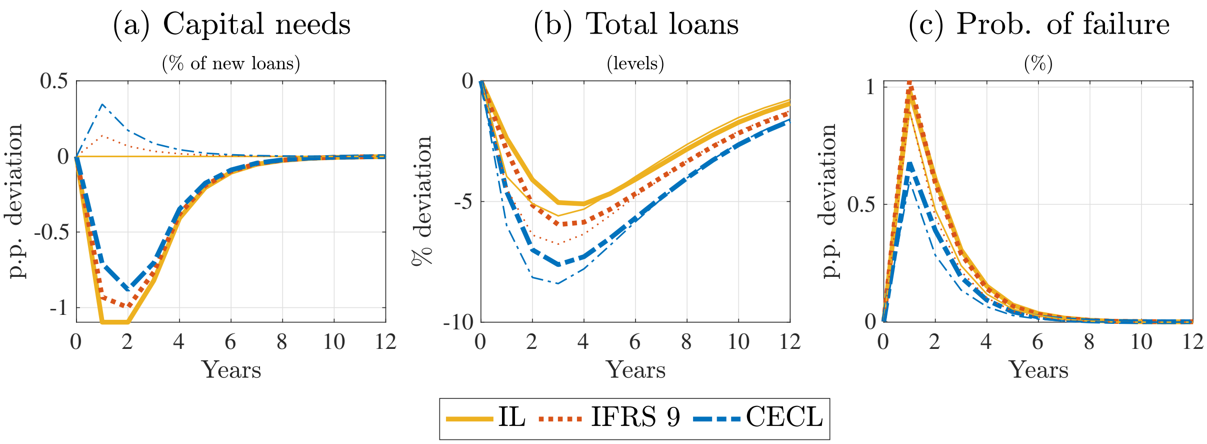
and $\tau_0 = 0$, where $t = 0$ is the year in which the policy is first introduced. Including τ_t in the optimization problem of the bank as an additional state variable allows us to adopt the following state-contingent specification of the CBR parameter:

$$\kappa_t = \begin{cases} 0.3125, & \text{if } \tau_t \in \{0, 1\}, \\ 0.375, & \text{if } \tau_t = 2, \\ 0.4375, & \text{if } \tau_t \geq 3. \end{cases} \tag{27}$$

According to (27), the fully-loaded CCyB, equal to 0.125 (or, equivalently, 1% of the bank's RWAs), is reached once an expansion phase lasts three years or more ($\tau_t \geq 3$) and sits on top of the baseline level of 0.3125 (or 2.5% of RWAs) of the CBR. The CCyB rate is zero when the economy is in the contraction state ($\tau_t = 0$) or just one year after starting an expansion

[29] Starting loading the CCyB in the second year after a contractionary phase ends is consistent with the one-year notice period that Basel III specifies for changes in the CCyB.

Figure 4: Contraction arrival with the release of an added CCyB



Notes: Thick lines represent the average response to the arrival of a contraction under an active CCyB policy with a neutral rate of 1% defined as in (27). The thin lines correspond to the baseline case in which the CBR is constant at 2.5%. The variables depicted in each panel are defined as follows: (a) Capital needs = $\alpha_1(s_t) + (1 + \kappa_t)\gamma_1(s_t)$; (b) Total loans = $L_t + N_t$; (c) Prob. of failure: Prob$(E_{t+1} < \underline{E}_{t+1})$.

phase ($\tau_t = 1$), and is loaded at the transitional rate of 0.5% in the second expansion year ($\tau_t = 2$).

Figure 4 provides a first visual description of the countercyclical effectiveness of this policy. The thick lines show the average response trajectories of key endogenous variables to the arrival of a contraction when the CCyB is fully loaded CCyB. For comparison, the thin lines show the average trajectories without the policy (as in Figure 3). Under the three provisioning standards that we consider, the policy provides a significant capital relief during the contraction. In fact, the capital relief exceeds the increase in capital needs that occurs without an active CCyB policy (panel (a)). This relief reduces both the weighted average cost of funding new loans (relevant if the bank is not capital constrained) and the scarcity of capital (relevant if the bank is capital constrained) and mitigates the cyclical contraction in bank credit (panel (b)). This effect, however, only offsets a small part of the cyclical variation in total loans, which is mainly due to the lower fundamental profitability of originating loans

Table 5: Endogenous variables with an added 1% CCyB

	IL				IFRS 9				CECL			
	Avg.	Boom	Bust	Diff.	Avg.	Boom	Bust	Diff.	Avg.	Boom	Bust	Diff.
Capital needs	15.4	15.3	15.6	0.3	15.8	15.7	16.3	0.7	17.6	17.4	18.3	0.8
of which policy impact	0.8	1.0	-0.1	-1.1	0.7	0.9	-0.1	-1.0	0.7	0.9	-0.1	-1.0
Total loans*	94.3	95.3	90.9	-4.6	94.0	95.2	90.2	-5.3	78.7	80.1	74.1	-7.5
of which policy impact	-5.7	-6.2	-4.1	2.1	-5.1	-5.6	-3.6	2.0	-9.0	-9.4	-7.7	1.7
Dividend yield	7.5	7.2	8.5	1.2	8.1	8.0	8.4	0.4	8.6	8.2	9.9	1.7
of which policy impact	-0.5	-1.6	3.1	4.7	-0.6	-1.7	3.1	4.8	-0.6	-1.7	3.1	4.8
Prob(dividend=0)	10.7	8.8	16.8	8.0	9.5	7.3	16.8	9.5	8.1	6.5	13.5	7.0
of which policy impact	0.8	2.5	-4.9	-7.4	0.5	1.9	-4.4	-6.3	0.3	1.7	-4.0	-5.7
Bank failure rate	0.6	0.1	2.1	2.0	0.6	0.1	2.1	2.0	0.4	0.1	1.6	1.5
of which policy impact	-0.2	-0.1	-0.4	-0.4	-0.2	-0.1	-0.5	-0.4	-0.1	-0.0	-0.4	-0.3

Note: All numbers represent percentages except for "Total loans" (indicated with *), whose unconditional and state contingent means are reported in levels (to be compared with the unconditional mean under IL provisions, which is normalized to 100); the mean bust-boom difference ("Diff.") for this variable is reported as a percentage of the corresponding unconditional mean. The second row for each variable describes differences with respect to the results without a CCyB reported in Table 4.

in the contraction state.[30] Importantly, the policy comes at a very small cost in terms of bank solvency (panel (c)): the cyclical variation in the bank failure probability is almost the same as without the policy.

However, beyond affecting cyclicality, an active CCyB policy also has sizable implications for the unconditional mean values of relevant variables, including capital needs, total lending, and the probability of bank failure. This can be seen in Table 5, which reports the unconditional means, state-contingent means, and mean cross-state variation ("Diff.") of a selection of endogenous variables under the policy, as well as (in the second row for each variable) the difference with respect to the value of the same statistic without the policy.

The policy implies an increase in the mean capital needs of the bank during expansions, causing a quite sizable reduction in loan origination and, consequently, mean total loans. The fall is particularly strong under CECL (-9.0 pp) compared with IL (-5.7 pp) and IFRS 9 (-5.1 pp). The other side of these effects is the increase in bank solvency: relative to the no-policy benchmark, the mean probability of bank failure in contraction periods falls by 0.4 to 0.5 pp across provisioning regimes, and by 0.1 to 0.2 pp unconditionally.

The impact of the policy on average dividend yields during contractions or the average

[30] Recall that, in our formulation, newly originated loans are as good as any standard-quality loan, but standard-quality loans feature larger credit risk during contractions than during expansions.

frequency with which the bank has to cancel its dividends during contractions (because of the MDA constraints implied by the violation of the CBR) suggest success in reducing emerging capital scarcity problems during downturns and thus the procyclical credit supply effects associated with them. However, such stabilizing effects come at a large cost in terms of average credit, an impact that might have been overseen in recent policy discussions about the virtues of adopting a positive neutral CCyB rate.

The optimizing bank in our calibrated model reacts to the higher on average CBR by originating less new loans across the cycle. The bank certainly faces a less likely (and lower) capital scarcity problem during busts, but this is not enough to increase lending during busts relative to its level without the policy. Intuitively, the prospect of facing higher capital needs when back into the boom makes the bank's weighted average cost of funds higher than without the policy and it turns out that this profitability effect dominates, on average, the capital-scarcity effect. As emphasized, however, this assessment is compatible with the policy being able to prevent a credit crunch in situations where the bank suffers extreme loan losses (which in the model happens when there is a large realization of the default rates represented by ω_{jt+1} in Figure 1). As shown and discussed in subsection **??**, in such tail events, the active added CCyB considered in this section contributes to sustain the origination of new loans.

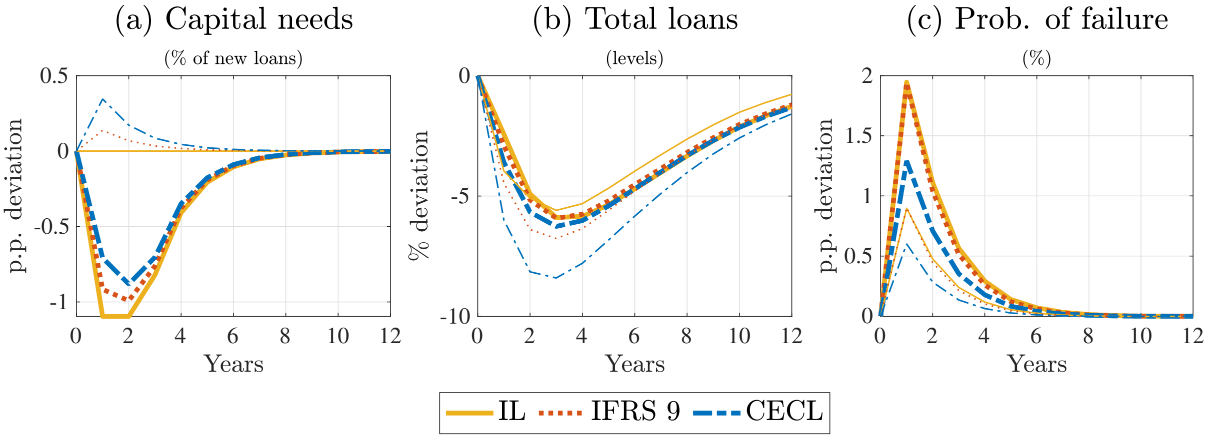
6.2 Capital-neutral implementation of the CCyB

We now consider the case in which the adoption of an active CCyB policy identical to the one analyzed above is combined with a permanent reduction of 1% in other components of the CBR. In our analysis this implies reducing the baseline CBR level from 0.3125 (2.5% of RWAs) to 0.1875 (1.5% of RWAs). The state-contingent overall CBR rate is then specified as follows:

$$\kappa_t = \begin{cases} 0.1875, & \text{if } \tau_t \in [0,1], \\ 0.25, & \text{if } \tau_t = 2, \\ 0.3125, & \text{if } \tau_t \geq 3. \end{cases} \tag{28}$$

The thick lines in Figure 5 show the average response trajectories to the arrival of a

Figure 5: Contraction arrival with the release of a capital-neutral CCyB



Notes: Thick lines represent the average responses to the arrival of a contraction under an active CCyB policy with a neutral rate of 1% defined as in (28). The thin lines correspond to the baseline case in which the CBR is constant at 2.5%. The variables depicted in each panel are defined as follows: (a) Capital needs $= \alpha_1(s_t) + (1 + \kappa_t)\gamma_1(s_t)$; (b) Total loans $= L_t + N_t$; (c) Prob. of failure: $\text{Prob}(E_{t+1} < \underline{E}_{t+1})$.

contraction under this policy, while the thin lines again describe the mean trajectories without the policy. By construction, the capital relief provided by this policy design (in terms of capital needs per unit of new lending) when a contraction arrives (panel (a)) is the same as under the previous design. However, such a relief applies from a lower level of the CBR than in Figure 4, which explains the differences in results in panels (b) and (c).

The capital-neutral design shows similar effectiveness as the added-CCyB design in countering the cyclicality of total loans under IFRS 9 provisioning, but entails significantly greater effectiveness under CECL and somewhat lower effectiveness under IL. This suggests that the level of the CBR (affecting the weighted average cost of capital) plays an important role in determining the sensitivity of new lending to changes in capital needs. It also plays a role in determining the cyclicality of bank solvency. Opposite to what happened under the added-CCyB design, the capital-neutral design roughly doubles (under any of the provisioning standards) the rise in the bank's probability of failure following the arrival of a contraction (panel (c)).

Table 6 confirms the presence of a trade-off between, on the one hand, stimulating and stabilizing credit and, on the other, preserving solvency, especially during contractions. As

Table 6: Endogenous variables with a capital-neutral 1% CCyB

	IL				IFRS 9				CECL			
	Avg.	Boom	Bust	Diff.	Avg.	Boom	Bust	Diff.	Avg.	Boom	Bust	Diff.
Capital needs	14.1	14.1	14.3	0.2	14.6	14.5	15.1	0.7	16.5	16.3	17.1	0.8
of which policy impact	-0.5	-0.2	-1.4	-1.1	-0.5	-0.2	-1.3	-1.0	-0.5	-0.2	-1.3	-1.1
Total loans*	101.5	102.6	97.8	-4.6	100.9	102.2	96.7	-5.3	89.8	91.1	85.5	-6.1
of which policy impact	1.5	1.0	3.3	2.1	1.8	1.3	3.5	1.9	3.8	3.1	6.6	3.1
Dividend yield	8.1	7.8	9.1	1.4	8.8	8.7	9.0	0.3	9.2	9.1	9.7	0.6
of which policy impact	0.1	-1.1	3.8	4.8	0.1	-1.0	3.7	4.8	0.1	-0.8	2.9	3.7
Prob(dividend=0)	10.2	8.0	17.4	9.4	9.5	7.0	18.1	11.2	7.9	5.7	14.9	9.2
of which policy impact	0.3	1.6	-4.3	-6.0	0.5	1.6	-3.0	-4.6	0.1	0.9	-2.6	-3.5
Bank failure rate	0.9	0.2	3.3	3.0	0.9	0.2	3.3	3.1	0.7	0.1	2.4	2.3
of which policy impact	0.2	0.0	0.8	0.7	0.2	0.0	0.7	0.7	0.1	0.0	0.5	0.5

Note: All numbers represent percentages except for "Total loans" (indicated with *), whose unconditional and state contingent means are reported in levels (to be compared with the unconditional mean under IL provisions, which is normalized to 100); the mean bust-boom difference ("Diff.") for this variable is reported as a percentage of the corresponding unconditional mean. The second row for each variable describes differences with respect to the results without a CCyB reported in Table 4.

shown in the second lines for each variable, relative to the no policy baseline, the capital-neutral CCyB design is expansive for total loans both on average and across states, but increases the probability of bank failure in a significant manner, especially during contractions. Interestingly, the ratio between gains in terms of level and stability of lending and losses in terms of solvency is more favorable under CECL than under IL and IFRS 9. This comes from the fact that, as discussed in earlier sections of the paper, CECL effectively implies greater levels of capitalization and, consequently, lower lending and higher solvency than the other standards. Starting from such levels, the 1% reduction in the non-CCyB part of the CBR which comes with this policy design contributes to make the outcomes under CECL closer to those obtained under IL and IFRS 9 with the added-CCyB policy design.

All in all, these results show that discussions on countercyclical capital-based policies for banks cannot be isolated from discussions about the adequate average level of capital. Countering cyclicality (including the one potentially coming from more or less procyclical provisioning standards) with capital relief measures is only feasible up to some extent (since they may not reverse the fact that the fundamental profitability of new lending is lower during contractions) and will typically involve a cost either in terms of bank solvency (if the relief leads to lower than baseline capitalization levels) or in terms of average lending (if the relief operates over previously elevated-above-the-baseline capitalization levels).

7 Conclusions

The Great Recession led to a shift in bank loan loss provisioning from an incurred loss to an expected credit loss approach. We have developed a dynamic banking model with a recursive ratings-migration structure to assess the impact of these standards on bank performance. Our novel use of a rating-migration setup mirrors risk management practices, capturing realistic credit risk fluctuations driven by economic cycles. The bank adjusts loan origination, capital structure, and dividends in response to risk changes. Provisioning rules and capital requirements shape provisioning and capitalization, influencing cyclical shock transmission. We calibrate the model to a euro area bank with a typical corporate loan portfolio.

Compared to the IL approach, the new standards lead to higher average loan loss provisions, raising the bank's funding costs and discouraging lending. These effects are stronger under CECL, which considers lifetime credit losses, than under IFRS 9, which applies a one-year horizon for stage 1 loans. The new standards also amplify the procyclicality of bank lending by triggering sharper increases in provisions at the onset of downturns. CECL's stronger procyclicality stems mainly from profitability effects, while IFRS 9's is driven more by capital constraints arising from large loan losses. IFRS 9 and CECL also differ in their implications for bank solvency and for the bank's ability to comply with the CBR and avoid restrictions on dividends or new lending. CECL induces the bank to effectively operate with lower leverage, reducing its probability of failure and improving its capacity to comply with the CBR. In contrast, IFRS 9 performs very similarly to the IL standard along these dimensions.

We complement the evaluation of the new standards with the assessment of the CCyB's effectiveness in stabilizing bank credit supply, highlighting key policy trade-offs. When added to the benchmark level of the CBR, the CCyB reduces lending cyclicality without raising failure risk but significantly lowers average lending. Alternatively, pairing a positive neutral CCyB rate with a permanent CBR stabilizes lending without reducing average lending but weakens bank solvency, especially in downturns. The general lesson is that the capacity to counter cyclicality with capital relief measures is limited (since the decline in loan origination during contractions is primarily driven by the fundamental profitability of the new loans) and typically involves a cost in terms of either bank solvency or average lending.

Finally, we conclude discussing potential extensions of our work. Readers should be cautious in extrapolating our quantitative findings to banks or banking systems with credit exposures featuring maturities, risk profiles, or sensitivities to the business cycle different from those in our calibration. Assessing the impact of the new provisioning standards in those cases would require appropriate model recalibration. In this regard, the model's value as an analytical tool is as important as the quantitative insights derived from its current calibration.

From a modeling perspective, our work could be extended in several directions. The current two-state representation of the business cycle could be expanded to include three or more states. The bank's objective of maximizing the expected discounted value of dividends could be adjusted to incorporate preferences for dividend smoothing or minimum payout targets. Additionally, the assumption that equity growth relies solely on retained earnings could be relaxed to allow for (costly) equity issuance. Further refinements could include loan origination across different credit qualities, incorporating a costly screening process to determine loan composition. Extensions could also explore the bank's role in managing the resolution speed of non-performing loans or influencing the probability of credit quality improvement for deteriorated loans.

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Appendices

A Loan loss provisions

In this Appendix we derive closed-form solutions for the provisioning coefficients under each accounting regime described in Section 3.

Incurred losses: Under this provisioning standard, only the impaired loans in our category $j = 3$ carry a strictly positive provisioning coefficient. Such a coefficient equals the expected LGD of the loan in the corresponding aggregate state s. The relevant expected LGDs are recursively defined by the system of equations described in (16), which is reproduced here for convenience:

$$LGD(s) = \sum_{s' \in S} p_{ss'} \left[\delta_3 \lambda(s') + (1 - \delta_3) LGD(s') \right],$$

for $s \in S$. In matrix form, with two aggregate states, this system can be expressed as:

$$\underbrace{\begin{bmatrix} LGD(1) \\ LGD(2) \end{bmatrix}}_{\hat{\boldsymbol{\lambda}}} = \delta_3 \underbrace{\begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix}}_{\boldsymbol{P}} \underbrace{\begin{bmatrix} \lambda(1) \\ \lambda(2) \end{bmatrix}}_{\boldsymbol{\lambda}} + (1 - \delta_3) \underbrace{\begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix}}_{\boldsymbol{P}} \underbrace{\begin{bmatrix} LGD(1) \\ LGD(2) \end{bmatrix}}_{\hat{\boldsymbol{\lambda}}},$$

from where it is possible to explicitly solve for $\hat{\boldsymbol{\lambda}}$:

$$\hat{\boldsymbol{\lambda}} = [\boldsymbol{I}_2 - (1 - \delta_3)\boldsymbol{P}]^{-1} \delta_3 \boldsymbol{P} \boldsymbol{\lambda}, \tag{A.1}$$

where $\boldsymbol{I}_2$ denotes the 2×2 identity matrix.

Loan loss provisions under IFRS 9: As stated in the main text, the provisioning coefficients under IRFS 9 can be expressed as:

$$\alpha^{\text{IFRS 9}}(s) = [\alpha_1^{\text{1Y}}(s), \alpha_2^{\text{LT}}(s), LGD(s)]', \tag{A.2}$$

with a one-year expected loss coefficient applied to loans rated $j = 1$ and a lifetime expected loss coefficient applied to loans rates $j = 2$. The coefficients of discounted one-year-ahead expected losses for any $j \in \{1, 2\}$ in a given state s can be calculated as:

$$\alpha_j^{1\mathrm{Y}}(s) = \frac{1}{1 + r_L} \sum_{s' \in S} p_{ss'} PD_j(s') \left[\delta_3 \lambda(s') + (1 - \delta_3) LGD(s')\right].$$

Hence, in matrix form and with two aggregate states, they can be expressed as:

$$\underbrace{\begin{bmatrix} \alpha_j^{1\mathrm{Y}}(1) \\ \alpha_j^{1\mathrm{Y}}(2) \end{bmatrix}}_{\boldsymbol{\alpha}_j^{1\mathrm{Y}}} = \frac{\delta_3}{1 + r_L} \underbrace{\begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix}}_{\boldsymbol{P}} \underbrace{\begin{bmatrix} PD_j(1) & 0 \\ 0 & PD_j(2) \end{bmatrix}}_{\boldsymbol{\Omega}_j} \underbrace{\begin{bmatrix} \lambda(1) \\ \lambda(2) \end{bmatrix}}_{\boldsymbol{\lambda}} + \frac{1 - \delta_3}{1 + r_L} \underbrace{\begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix}}_{\boldsymbol{P}} \underbrace{\begin{bmatrix} LGD(1) \\ LGD(2) \end{bmatrix}}_{\hat{\boldsymbol{\lambda}}},$$

or just

$$\boldsymbol{\alpha}_j^{1\mathrm{Y}} = \frac{\delta_3}{1 + r_L} \boldsymbol{P} \boldsymbol{\Omega}_{\boldsymbol{j}} \boldsymbol{\lambda} + \frac{1 - \delta_3}{1 + r_L} \boldsymbol{P} \hat{\boldsymbol{\lambda}},$$

where $\hat{\boldsymbol{\lambda}}$ is given by (A.1).

As explained in the main text, obtaining the discounted lifetime expected loss coefficients for loans rated $j \in \{1, 2\}$ in a given state s requires solving the system of equations given by the following recursive formulas:

$$\alpha_j^{\mathrm{LT}}(s) = \frac{1}{1 + r_L} \sum_{s' \in S} p_{ss'} \left\{ PD_j(s') \left[\delta_3 \lambda(s') + (1 - \delta_3) LGD(s')\right] \right.$$
$$\left. + (1 - PD_j(s')) \sum_{j'=1,2} (1 - \delta_{j'}) a_{jj'}(s') \alpha_{j'}^{\mathrm{LT}}(s') \right\},$$

for all $j \in \{1, 2\}$ and $s \in S$. In matrix form, with two aggregate states, this system can be written as:

$$\underbrace{\begin{bmatrix}\alpha_j^{\mathrm{LT}}(1)\\ \alpha_j^{\mathrm{LT}}(2)\end{bmatrix}}_{\boldsymbol{\alpha}_j^{\mathrm{LT}}} = \underbrace{\begin{bmatrix}\alpha_j^{\mathrm{1Y}}(1)\\ \alpha_j^{\mathrm{1Y}}(2)\end{bmatrix}}_{\boldsymbol{\alpha}_j^{\mathrm{1Y}}} + \frac{1-\delta_j}{1+r_L}\underbrace{\begin{bmatrix}p_{11} & p_{12}\\ p_{21} & p_{22}\end{bmatrix}}_{\boldsymbol{P}}\underbrace{\begin{bmatrix}1-PD_j(1) & 0\\ 0 & 1-PD_j(2)\end{bmatrix}}_{\boldsymbol{I}_2-\boldsymbol{\Omega}_j}$$
$$\times\underbrace{\begin{bmatrix}a_{j1}(1) & 0 & a_{j2}(1) & 0\\ 0 & a_{j1}(2) & 0 & a_{j2}(2)\end{bmatrix}}_{\boldsymbol{A}_j}\underbrace{\begin{bmatrix}\boldsymbol{\alpha}_1^{\mathrm{LT}}\\ \boldsymbol{\alpha}_2^{\mathrm{LT}}\end{bmatrix}}_{\bar{\boldsymbol{\alpha}}^{\mathrm{LT}}},$$

for $j \in \{1,2\}$. More compactly, this can be written as:

$$\bar{\boldsymbol{\alpha}}^{LT} = \bar{\boldsymbol{\alpha}}^{1Y} + \frac{1}{1+r_L}\begin{bmatrix}(1-\delta_1)\boldsymbol{P}(\boldsymbol{I}_2-\boldsymbol{\Omega}_1) & 0\\ 0 & (1-\delta_2)\boldsymbol{P}(\boldsymbol{I}_2-\boldsymbol{\Omega}_2)\end{bmatrix}\begin{bmatrix}\boldsymbol{A}_1\\ \boldsymbol{A}_2\end{bmatrix}\bar{\boldsymbol{\alpha}}^{LT},$$

where $\bar{\boldsymbol{\alpha}}^{\mathrm{LT}} \equiv [\alpha_1^{\mathrm{LT}}(1), \alpha_1^{\mathrm{LT}}(2), \alpha_2^{\mathrm{LT}}(1), \alpha_2^{\mathrm{LT}}(2)]'$ and $\bar{\boldsymbol{\alpha}}^{\mathrm{1Y}} \equiv [\alpha_1^{\mathrm{1Y}}(1), \alpha_1^{\mathrm{1Y}}(2), \alpha_2^{\mathrm{1Y}}(1), \alpha_2^{\mathrm{1Y}}(2)]'$. Solving for $\bar{\boldsymbol{\alpha}}^{\mathrm{LT}}$, we obtain:

$$\bar{\boldsymbol{\alpha}}^{\mathrm{LT}} = \left\{\boldsymbol{I}_4 - \frac{1}{1+r_L}\begin{bmatrix}(1-\delta_1)\boldsymbol{P}(\boldsymbol{I}_2-\boldsymbol{\Omega}_1) & 0\\ 0 & (1-\delta_2)\boldsymbol{P}(\boldsymbol{I}_2-\boldsymbol{\Omega}_2)\end{bmatrix}\begin{bmatrix}\boldsymbol{A}_1\\ \boldsymbol{A}_2\end{bmatrix}\right\}^{-1}\bar{\boldsymbol{\alpha}}^{\mathrm{1Y}}.$$

From the vectors $\bar{\boldsymbol{\alpha}}^{\mathrm{1Y}}$ and $\bar{\boldsymbol{\alpha}}^{\mathrm{LT}}$, it is immediate to extract the components needed to feed (A.2).

Current expected credit losses (CECL): Computing the discounted lifetime expected loss coefficients for the loans in categories $j \in \{1,2\}$ requires solving the system of equations in (21), which is reproduced here for convenience:

$$\begin{aligned}\alpha_j^{\mathrm{CECL}}(s) \;\; = \;\; & \frac{1}{1+r}\sum_{s'\in S} p_{ss'}\Bigg\{PD_j(s')[\delta_3\lambda(s') + (1-\delta_3)LGD(s')]\\ & +(1-PD_j(s'))\sum_{j'=1,2} a_{jj'}(s')(1-\delta_{j'})\alpha_{j'}^{\mathrm{CECL}}(s')\Bigg\},\end{aligned}$$

for $j \in \{1,2\}$ and $s \in S$. Reproducing the steps that led above to the closed-form solution for $\bar{\boldsymbol{\alpha}}^{\mathrm{LT}}$, the provisioning coefficients under the CECL standard with two aggregate states can be found as:

$$\bar{\boldsymbol{\alpha}}^{\mathrm{CECL}} = \left\{ \boldsymbol{I}_4 - \frac{1}{1+r} \begin{bmatrix} (1-\delta_1)\boldsymbol{P}(\boldsymbol{I}_2 - \boldsymbol{\Omega}_1) & 0 \\ 0 & (1-\delta_2)\boldsymbol{P}(\boldsymbol{I}_2 - \boldsymbol{\Omega}_2) \end{bmatrix} \begin{bmatrix} \boldsymbol{A}_1 \\ \boldsymbol{A}_2 \end{bmatrix} \right\}^{-1} \bar{\boldsymbol{\alpha}}^{1Y,r},$$

where $\bar{\boldsymbol{\alpha}}^{CECL} \equiv [\alpha_1^{CECL}(1), \alpha_1^{CECL}(2), \alpha_2^{CECL}(1), \alpha_2^{CECL}(2)]'$, and $\bar{\boldsymbol{\alpha}}^{1Y,r}$ denotes discounted one-year-ahead expected loss coefficients akin to those in $\bar{\boldsymbol{\alpha}}^{1Y}$ but using the risk-free rate r, instead of the loan rate r_L, as a discount rate.

B Calibration of the credit risk parameters

We calibrate the migration and default probabilities of our two non-default loan categories (and their variation across aggregate states) using S&P rating migration data that refers to seven non-default rating categories, namely AAA, AA, A, BBB, BB, B and CCC/C, and covers the period from 1981 to 2017.[31] To explain the procedure, we first refer to a version of the model with a single aggregate state and then explain how to extend the approach to the case with two aggregate states.

B.1 Single aggregate state case

A first stage in the process is to collapse the seven category representation in this data into the two category representation in our model. We do that by essentially treating each of our two performing categories as a weighted average of some of the seven categories in the data. To obtain the weighting factors, we first abstract from time or state variation in migration and default rates across the original seven categories. So we consider the 7×7 matrix $\widetilde{\mathbf{B}}$ obtained by averaging the yearly matrices provided by S&P global corporate default studies

[31] We use reports equivalent to Standard & Poor's (2016) published in years 2003 and 2005-2018, which provide the relevant information for each of the years between 1981 and 2017.

covering the period from 1981 to 2017:

$$\widetilde{\mathbf{B}} = \begin{bmatrix} 0.8884 & 0.0051 & 0.0005 & 0.0002 & 0.0002 & 0.0000 & 0.0006 \\ 0.1047 & 0.8880 & 0.0201 & 0.0020 & 0.0008 & 0.0006 & 0.0000 \\ 0.0045 & 0.0997 & 0.9185 & 0.0452 & 0.0032 & 0.0024 & 0.0021 \\ 0.0010 & 0.0053 & 0.0545 & 0.8956 & 0.0612 & 0.0032 & 0.0038 \\ 0.0005 & 0.0006 & 0.0041 & 0.0457 & 0.8377 & 0.0608 & 0.0109 \\ 0.0003 & 0.0008 & 0.0016 & 0.0079 & 0.0798 & 0.8410 & 0.1412 \\ 0.0006 & 0.0002 & 0.0002 & 0.0012 & 0.0075 & 0.0439 & 0.5693 \end{bmatrix}. \tag{B.1}$$

This matrix describes the average yearly migrations across the seven non-default ratings in the main S&P classification.[32] According to the convention used by S&P, each element $\tilde{b}_{j'j}$ of this matrix denotes a loan's probability of migrating to S&P rating j' from S&P rating j, and the yearly probability of default corresponding to S&P rating j can be found as $\widetilde{PD}_j = 1 - \sum_{j'=1}^{7} \tilde{b}_{j'j}$, which implies the following vector of PDs:

$$\widetilde{\mathbf{PD}} = [0.0000, 0.0002, 0.0004, 0.0024, 0.009, 0.0481, 0.2720]. \tag{B.2}$$

In this first step, we want to collapse $\widetilde{\mathbf{B}}$ into the 2×2 transition matrix $\mathbf{B}$ with elements $b_{j'j}$ that, abstracting from cyclicality, would represent transitions across the two performing loan categories in our analysis, implying probabilities of default $PD_j = 1 - \sum_{j'=1}^{2} b_{j'j}$ for each of such categories $j \in \{1, 2\}$. We do this by assuming that the S&P categories 1 to 5 (AAA, AA, A, BBB, BB) correspond to our category 1 and S&P categories 6 and 7 (B, CCC/C) to our category 2. We also assume that all the new loans of the bank belong to the BB category in the year of origination and consider a hypothetical steady-state situation in which the volume of yearly newly originated loans of the bank is normalized to one so that the vector representing the new loans under the S&P classification is $\widetilde{\mathbf{N}} = [0, 0, 0, 0, 1, 0, 0]'$.

[32] We have re-weighted the original migration rates in S&P matrices to avoid having "non-rated" as an eighth possible non-default category to which to migrate.

Portfolio dynamics across the seven loan categories in this steady-state setup can be represented as

$$\mathbf{Z}^* = \widetilde{\mathbf{M}}\mathbf{Z}^* + \widetilde{\mathbf{N}}, \tag{B.3}$$

which implicitly defines the *steady-state portfolio* $\mathbf{Z}^*$, whose closed-from expression is $\mathbf{Z}^* = (\boldsymbol{I}_7 - \widetilde{\mathbf{M}})^{-1}\boldsymbol{I}_7\widetilde{\mathbf{N}}$, with elements z_j^* for $j \in \{1, .., 7\}$, where $\boldsymbol{I}_7$ is the 7×7 identity matrix and the matrix $\widetilde{\mathbf{M}}$ has elements $\widetilde{m}_{j'j} = (1 - \delta_{j'})\widetilde{b}_{j'j}$, with $\delta_{j'}$ denoting the (independent) probability of a loan rated j' maturing at the end of any year t (as in our baseline calibration we set $\delta_j = 0.2$ for all the non-defaulting categories). From here, the "collapsed" steady-state portfolio $\mathbf{X}^*$ associated with $\mathbf{Z}^*$ would be the one with elements $x_1^* = \sum_{j=1}^{5} z_j^*$ and $x_2^* = \sum_{j=6}^{7} z_j^*$.

The composition in terms of the original S&P categories of the collapsed steady-state portfolio X^* can then be used to find migration and default rates that would describe the dynamics of the collapsed portfolio in a way consistent with the S&P data. Such rates would just be weighted averages of those in the composing S&P categories. Specifically, abstracting from state contingency and the randomness of the realized default rate, the equivalent to the 3×3 transition matrix $\mathbf{M}_{t+1}$ in (2) would be

$$\widehat{\mathbf{M}} = \begin{bmatrix} \frac{\sum_{j'=1}^{5}\sum_{j=1}^{5}\widetilde{m}_{j'j}z_j^*}{x_1^*} & \frac{\sum_{j'=1}^{5}\sum_{j=6}^{7}\widetilde{m}_{j'j}z_j^*}{x_2^*} & 0 \\ \frac{\sum_{j'=6}^{7}\sum_{j=1}^{5}\widetilde{m}_{j'j}z_j^*}{x_1^*} & \frac{\sum_{j'=6}^{7}\sum_{j=6}^{7}\widetilde{m}_{j'j}z_j^*}{x_2^*} & 0 \\ \widehat{PD}_1(1-\delta_3) & \widehat{PD}_2(1-\delta_3) & (1-\delta_3) \end{bmatrix}, \tag{B.4}$$

with

$$\widehat{PD}_1 = \frac{\sum_{j=1}^{5}\widetilde{PD}_j z_j^*}{x_1^*}, \tag{B.5}$$

and

$$\widehat{PD}_2 = \frac{\sum_{j=6}^{7}\widetilde{PD}_j z_j^*}{x_2^*}, \tag{B.6}$$

describing the default rates of the collapsed categories. The parameters $a_{jj'}$ of a single aggregate state version of our formulation could be recovered from the corresponding elements $\widehat{m}_{j'j}$ in (B.4) (notice the change in convention regarding the departure and arrival states in the subscripts of each of these variables) after discounting the impact of the underlying default and maturity rates on the transition rates contained in such elements:

$$a_{jj'} = \frac{\widehat{m}_{j'j}}{(1-\widehat{PD}_j)(1-\delta_{j'})}. \tag{B.7}$$

B.2 Extension to the case with two aggregate states

Our formulation of credit risk dynamics in (2) generalizes the specification discussed in the previous subsection by allowing (i) the realized default rates for each performing category, ω_{jt+1}, to randomly vary around their expected value $PD_j(s_{t+1})$ according to the single risk-factor model of Vasicek (2002) and (ii) the migration rates across performing categories between periods t and $t+1$, $a_{jj'}(s_{t+1})$, to depend on the aggregate state s_{t+1}. We calibrate the elements of

$$\mathbb{E}_t(\mathbf{M}_{t+1}|s_{t+1}{=}s) = \begin{bmatrix} (1-PD_1(s))a_{11}(s)(1-\delta_1) & (1-PD_2(s))a_{21}(s)(1-\delta_1) & 0 \\ (1-PD_1(s))a_{12}(s)(1-\delta_2) & (1-PD_2(s))a_{22}(s)(1-\delta_2) & 0 \\ PD_1(s)(1-\delta_3) & PD_2(s)(1-\delta_3) & (1-\delta_3) \end{bmatrix}, \tag{B.8}$$

by identifying them with those of adjusted state-contingent versions $M(s)$ of the matrix $\widehat{M}$ found in (B.4).

First we find counterparts $\widehat{\mathbf{M}}(1)$ and $\widehat{\mathbf{M}}(2)$ of $\widehat{\mathbf{M}}$ by following a procedure analogous to that leading to (B.4) but starting from state-contingent versions, $\widetilde{\mathbf{B}}(1)$ and $\widetilde{\mathbf{B}}(2)$, of the 7×7 migration matrix $\widetilde{\mathbf{B}}$ in (B.1). As described in Section B.1, we can go from each $\widetilde{\mathbf{B}}(s)$ to the maturity-adjusted matrix $\widetilde{\mathbf{M}}(s)$ with elements $\widetilde{m}_{j'j}(s) = (1-\delta_{j'})\widetilde{b}_{j'j}$ and then find the elements of $\widehat{\mathbf{M}}(s)$ as weighted averages of the elements of $\widetilde{\mathbf{M}}(s)$. To keep things simple, we use the same unconditional weights as in (B.4), implying

$$\widehat{\mathbf{M}}(s) = \begin{bmatrix} \frac{\sum_{j'=1}^{5}\sum_{j=1}^{5}\widetilde{m}_{j'j}(s)z_j^*}{x_1^*} & \frac{\sum_{j'=1}^{5}\sum_{j=6}^{7}\widetilde{m}_{j'j}(s)z_j^*}{x_2^*} & 0 \\ \frac{\sum_{j'=6}^{7}\sum_{j=1}^{5}\widetilde{m}_{j'j}(s)z_j^*}{x_1^*} & \frac{\sum_{j'=6}^{7}\sum_{j=6}^{7}\widetilde{m}_{j'j}(s)z_j^*}{x_2^*} & 0 \\ \widehat{PD}_1(s)(1-\delta_3) & \widehat{PD}_2(s)(1-\delta_3) & (1-\delta_3) \end{bmatrix} \tag{B.9}$$

where

$$\widehat{PD}_1(s) = \frac{\sum_{j=1}^{5}\widetilde{PD}_j(s)z_j^*}{x_1^*}, \tag{B.10}$$

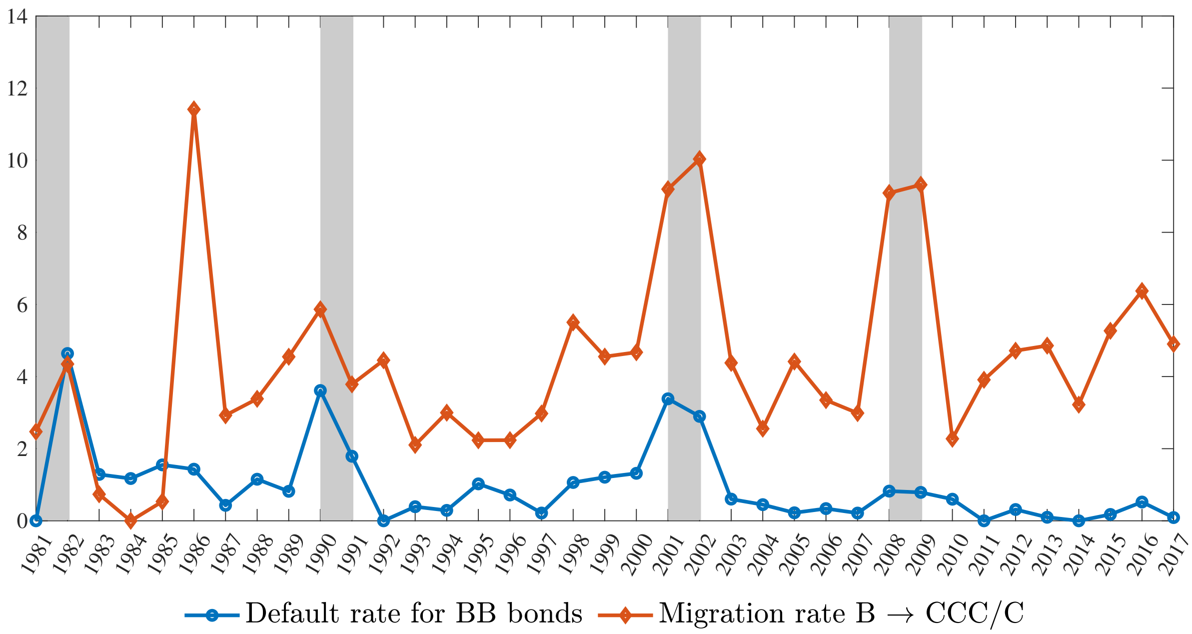
$$\widehat{PD}_2(s) = \frac{\sum_{j=6}^{7} \widetilde{PD}_j(s) z_j^*}{x_2^*}, \tag{B.11}$$

with $\widetilde{PD}_j(s) = 1 - \sum_{j'=1}^{7} \tilde{b}_{j'j}(s)$.

We calibrate $\widetilde{\mathbf{B}}(1)$ and $\widetilde{\mathbf{B}}(2)$ by exploring the business cycle sensitivity of S&P yearly migration matrices that were used previously to find $\widetilde{\mathbf{B}}$. Since we identify state $s = 1$ with expansion years and $s = 2$ with contraction years, we use the years identified by the NBER as the start of a recession in the US to identify the entry in state $s = 2$ and assume that each of the contractions observed in the period from 1981 to 2017 lasted exactly two years. This is consistent with the NBER dating of US recessions except for the recession started in 2001, to which the NBER attributes a duration of less than one year.[33] In fact, the behavior of corporate ratings migrations and defaults around such recession does not suggest it was shorter for our purposes than the other three. To illustrate this, Figure B.1 depicts the time series of two of the elements of the yearly default rates and migration matrices from S&P whose cyclical behavior is more evident: (i) the default rate among BB exposures ($\widetilde{PD}_5$) and (ii) the migration rate from a B rating to a CCC/C rating ($\tilde{b}_{7,6}$). Year 2002 emerges clearly as a year of marked deterioration in credit quality among exposures rated BB and B.

[33]See http://www.nber.org/cycles.html.

Figure B.1: Sensitivity of default and migrations rates to aggregate state



Notes: Selected yearly S&P default and downgrading rates. Grey bars identify 2-year periods following the start of NBER recessions.