Loan Loss Provisioning Requirements in a Dynamic Model of Banking[*]

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ABSTRACT

We investigate the effect of a provisioning requirement on bank loan supply and stability. A provisioning requirement affects the bank's intertemporal trade-offs through the minimum capital regulation and tax channels. Requiring higher provisions for future losses reduces default probability but may aggravate lending procyclicality. Both the cyclicality of a provisioning requirement and the tax treatment of provisions play a crucial role in whether higher provisions reduce lending procyclicality. We further calibrate our model to quantitatively assess the long-run effect of adopting a provisioning requirement implied by the expected loss approach (the new accounting standards of IFRS 9 and US GAAP).

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1 Introduction

When banks make loans, they are aware that a fraction of those loans will not be repaid. Therefore, banks have to periodically account for the loans that are unlikely to be repaid through loan loss provisions. There are, however, specific accounting requirements of how a bank should account for these loan losses. The recent financial crisis spurred discussion about these requirements and their effect on bank lending. In particular, the then-existing standards for loan loss recognition were blamed to contribute to the credit crunch as they did not allow for timely loss recognition (Financial Stability Forum Report (2009)).[1] The policy response was to move to a more "forward-looking" provisioning approach based on expected credit losses.[2] In this paper, we examine the effect of a provisioning requirement on bank loan supply and stability. We further quantitatively assess the long-term effects of adopting the expected provisioning approach on bank lending and stability.

A loan loss provision is a non-cash expense set aside as an allowance for impaired loans. It is an accounting entry that increases loan loss reserves (a contra asset account on the balance sheet) and reduces net income. Empirically, such provisions constitute a larger fraction of bank expenses (Huizinga and Laeven (2018)). As a result, they substantially reduce the bank's profit in financial statements thereby affecting regulatory capital. In the future when the losses realize they are charged-off against the loss reserves. The rules for loan loss provisioning for internationally active banks and U.S. based banks are formulated by the International Accounting Standards Board (IASB) and the US Financial Accounting Standards Board (FASB), respectively.

Provisioning for future losses is inherently a dynamic process. To examine the effect of a provisioning requirement on bank behavior, we develop a dynamic model of a bank in discrete-time infinite-horizon settings. Our model features endogenous loan origination, distributions, leverage,

[1] This issue was on the agenda of the 2009 G20 summit when the decision to "strengthen the accounting recognition of loan-loss provisions" was made. In the Declaration on the Strengthening the Financial System (G20 summit in London on 2 April 2009) the Leaders of G20 agreed to the following reforms among others: strengthen accounting recognition of loan-loss provisions by incorporating a broader range of credit information and improve accounting standards for provisioning.

[2] After the financial crisis, the International Accounting Standards Board (IASB) and the US Financial Accounting Standards Board (FASB) set in motion a joint project to improve accounting standards and in particular to develop methods of accounting for credit losses that would give more timely recognition of those losses thereby helping to reduce lending procyclicality. The expected loss approach has been adopted in the new International Financial Reporting Standard (IFRS) 9 which have been effective as of January 2018 and in the new US GAAP with the earliest mandatory effective date in 2020.

and default. The bank faces corporate taxes, external costs of issuing equity, and regulation. The regulation is characterized by the requirements on minimum capital and provisioning. The capital structure of the bank consists of fully insured short-term deposits and equity. The asset side is comprised of risky long-term loans with stochastic and time-varying default probabilities.

Using our model, we show that the provisioning requirement induces an intertemporal trade-off. Provisioning for loan losses either reduce dividends or increase required equity injection in the current period. At the same time, provisioning more today increases the next period reserves. Having higher reserves next period is beneficial as it improves the bank's loss absorption capacity. This translates either into higher dividends or lower equity injection next period.

We show that the effect of the provisioning requirement on bank loan supply and stability comes from two channels. The first channel - the capital regulation channel - arises due to the minimum capital regulation. The second channel - the tax channel - is due to the tax-deductibility of provisions.

The capital regulation channel of a provisioning requirement comes into play since the minimum capital regulation is formulated in terms of book values. Accounting-wise the net income before provisions is the source for both equity capital (through retention) and loan loss reserves (through provisioning). Thus, increasing provisions limits the bank's ability to increase equity through retention and vice versa. Therefore, the cost of provisioning is the same as those of equity. At the same time, both loan loss reserves and equity capital serve as a buffer to absorb the losses from outstanding loans when those are realized. Our model, therefore, highlights that the minimum capital requirement and the loss provisioning requirement are in effect substitutes. When provisions are not tax-deductible, increasing the provisioning requirement has the same effect on bank lending as that of increasing the minimum capital requirement.

This insight into the close relationship between the minimum capital and provisioning requirements is useful in two ways. First, it informs the policy debate around macro- and micro-prudential regulation that capital requirements and accounting standards on provisioning cannot be isolated from each other.[3] This has important policy implications, especially given that both the accounting standards for loan loss recognition and the capital regulation under Basel III are undergoing drastic modifications.

[3] This point has been already raised in Laeven and Majnoni (2003) and we formally show this in our model.

Second, it enables us to apply academic insights regarding the effect of capital regulation to understand the impact of provisioning requirements on bank loan supply and stability. For example, as in the case of capital requirements, increasing the required provisions for future losses reduces default probability as it improves the bank's loss absorption capacity. However, an important macroprudential aspect of increasing the provisioning requirement is how it is implemented over the cycle. This is because the design of the provisioning requirement in terms of its correlation with the business cycle has a direct effect on the cyclicality of bank lending. Similar to countercyclical capital buffer (CCyB), requiring the bank to provision more in good times helps to reduce lending procyclicality by enabling the bank to lend more in a contraction. In contrast, forcing the bank to provision more in bad times aggravates procyclicality and may severely contract overall lending activity.

The tax-deductibility of loan loss provisions gives rise to the tax channel of a provisioning requirement. Provisioning for loan losses allows the bank to defer taxes into the future resulting in a tax subsidy.[4] Due to loss limitations (i.e. the inability of the bank to perform interperiod reallocation and deduction of losses for tax purposes), the value of such a subsidy is larger in good times when profits are high. We show that by lending more in good times and less in bad, the bank can optimize with respect to this subsidy. Therefore, the tax channel of the provisioning requirement amplifies lending procyclicality. This, in turn, reduces the effectiveness of the provisioning requirement to improve stability. Relaxing loss limitations (for example, through loss carrybacks and carryforwards) could help to mitigate the procyclical effect of the tax channel as it would increase the value of the tax subsidy in bad times when the bank's profits are low thus allowing the bank to lend more.

Our analysis has an important implication for the recent regulatory effort to adopt a provisioning requirement based on the expected loss model (ELM). The ELM is designed to replace the incurred loss model (ILM) which was criticized for its procyclical effect on bank lending (Laeven and Majnoni (2003), Beatty and Liao (2011), and Huizinga and Laeven (2018)). Unlike the ILM, which restricts banks to recognize only those losses that have been factually identified, the ELM compels banks to also provision for losses that are based on the events that are expected to take place in the future.

[4] By provisioning for future losses the bank effectively brings future (expected) losses to the present and uses them to offset the current profits. If, however, in the future these losses do not materialize the bank would have to effectively repay these deferred taxes.

Under this new approach, loan loss provisions are intended to represent the discounted expected losses over some specified horizons.[5] This is believed to reduce lending procyclicality as it ensures that the bank is better prepared to accommodate expected losses without putting a toll on bank capital.

Although the higher provisions of the ELM are likely to increase the bank's loss absorption capacity and, thus, improve stability, our analysis suggests that the supply of bank loans is likely to contract and become more procyclical under the ELM. In line with our analysis, replacing the ILM with the ELM is equivalent to imposing a tighter yet more *countercyclical* capital requirement. Intuitively, when banks lack the capacity to anticipate the deterioration in aggregate conditions they front-load the increased expected losses only *at* the start of a contraction and not before it. This implies a more abrupt contraction in the bank's profits upon the arrival of a contraction which in turn increases procyclicality. As such, our analysis suggests that although the ELM is expected to improve stability, it is likely to aggravate lending procyclicality and reduce the overall supply of loans. Moreover, making expected provisions tax-deductible would further exacerbate the procyclical effect of the ELM.

We calibrate and simulate our model to quantitatively assess the long-term effects of adopting a provisions requirement based on the Expected Loss Model. This exercise brings to the fore the mechanisms discussed above by comparing the previous regulation with the proposed new ones.

Our model predicts economically significant lower levels of lending under both IFRS 9 and new US GAAP than under the ILM, especially conditional on contraction. We find that relative to the ILM the bank originates on average about 7% fewer new loans under the IFRS 9 of the new US GAAP, conditional on a contraction. Unconditionally, the average long-run decrease in new loans due to the adoption of the ELM is about 0.75%. We also find that IFRS 9 may exhibit slightly more procyclical impact on bank lending than the new US GAAP when the banks are subject to the Countercyclical Capital Buffer (CCyB). Under the CCyB the bank tends to hold a lower voluntary capital buffer which coupled with the more countercyclical provisioning requirement of IFRS 9 results in a more procyclical supply of loans. Our quantitative results further suggest that

[5] The International Financial Reporting Standards (IFRS) 9 adopt the Expected Credit Loss (ECL) model which is based on a mixed-horizon approach such that depending on loan's risk category the bank provision either for one-year or lifetime discounted expected losses. The Current Expected Credit Loss (CECL) model of the new US GAAP, on the other hand, requires banks to provision lifetime discounted expected losses on all loans.

replacing the ILM with either IFRS 9 or a new US GAAP version of the ELM lowers default probability.The new US GAAP is predicted to achieve a better reduction in default rate than IFRS 9 due to its larger loan loss reserves.The new US GAAP requires recognizing lifetime losses on all loans which result in larger reserves than under IFRS 9 which adopts a mixed-horizon approach. However, the tax-deductibility of expected provisions may substantially reduce the ability of the ELM to reduce default rates. Finally, we also consider an extension in which the bank's profits respond with a delay to the arrival of a contraction allowing the bank effectively to anticipate the aggregate shock. In this case, we find the procyclical effect of the ELM is slightly reduced by is not eliminated.

The rest of the paper proceeds as follows. Section 2 discusses related literature. Section 3 presents the dynamic model of a bank. In Section 4, we analytically derive and investigate the bank's optimal capital and lending policy for a given provisioning requirement. In Section 5, we calibrate and simulate our model to quantitatively assess the long-term implications of adopting provisioning requirements based on expected losses. Finally, Section 6 concludes.

2 Related Literature

Our paper contributes to the several strands of the literature. First, our paper relates to the large literature on the procyclical effect of bank regulation (Angelini, Enria, Neri, Panetta, and Quagliariello (2010), Repullo and Suarez (2012), Behn, Haselmann, and Wachtel (2016), Gersbach and Rochet (2017)). However, whereas this literature primarily examines the procyclical effect of capital regulation, we focus on the effect of loan loss provisioning regulation.

Second, our paper contributes to the literature on bank loan loss provisioning. Whereas the empirical literature on provisioning is relatively large (Ahmed, Takeda, and Thomas (1999), Laeven and Majnoni (2003), Beatty and Liao (2011), Bushman and Williams (2015), and Huizinga and Laeven (2018)), the theoretical literature is rather scarce. To the best of our knowledge, our paper is the first one to formally examine the effect of provisioning requirements on bank optimal behavior. Krüger, Rösch, and Scheule (2018)

Third, our paper contributes primarily to the literature assessing the cyclical impact of the expected credit loss approach of the new accounting standards. Early concerns about the potential procyclicality of the expected loss approach can be found in Laux (2012), Barclays (2017), and European Systemic Risk Board (2017). A few papers attempt to provide a quantitative assessment of the cyclical implications of the ELM. In a closely related paper by Abad and Suarez (2018), the authors examine the procyclical effect of the ELM on the bank's capital in a quantitative dynamic model of a bank with exogenous lending and heterogeneous loans. They show that the ELM aggravates the procyclicality of bank capital by amplifying the sensitivity of profits to a negative aggregate shock. By endogenizing the bank's decision over lending, financing, and default, our analysis goes a step further allowing us to evaluate the effect of the ELM on loan supply and bank stability.

Other papers adopt a different approach to quantifying the cyclical impact of the ILM. Using historical simulation methods, Krüger et al. (2018) show that had the banks in their sample followed the ELM they would have had lower levels of capital, especially during the crisis, and the bank capital would have been more procyclical. In a simple mortgage default and prepayment model, Chae, Sarama, Vojtech, and Wang (2019) show that the more accurately the banks can foresee macroeconomic conditions the more effective the ELM is at smoothing provisions compared to the ILM. Our contribution to this strand of the literature is that unlike other papers attempt to address the Lucas' critique by letting the bank to respond endogenously to the change in the provisioning requirement.

Finally, our paper broadly relates to the growing literature on the interaction between accounting practice, on the one hand, and financial stability and prudential regulation, on the other (see Goldstein and Sapra (2014) and Acharya and Ryan (2016) for a survey). Laux and Leuz (2010) provide critical analysis of the role of fair value accounting in the recent financial crisis. Mahieux, Sapra, and Zhang (2019) examine the effect of mandatory earlier loss recognition on bank risk taking. We contribute to this literature by pointing out that provisioning rules and capital regulation are the two sides of the same coin and, thus, should not be designed independently.

Methodologically, our model relates closely to the discrete-time dynamic investment models (Hennessy and Whited (2005), Hennessy and Whited (2007), and Strebulaev and Whited (2012)) Recently these models have been fruitfully applied in the banking literature. For example, Van den Heuvel (2009) examines the effect of the capital regulation channel of monetary policy on bank lending. De Nicolò, Gamba, and Lucchetta (2014) study the effect of microprudential regulation of Basel III on bank investment and capital structure decisions. Vuillemey (2019) investigates the banks' optimal hedging policy of the interest rate risk. Mankart, Michaelides, and Pagratis (forthcoming) analyze the banks' buffers under the new capital regulation of Basel III. Wang, Whited, Wu, and Xiao (2018) evaluate the impact of bank market power on the transition of monetary policy to borrowers. Behn, Daminato, and Salleo (2019) examine the interaction between capital and liquidity requirements.

3 Model

Time is discrete and the horizon is infinite. The bank's risk-neutral manager, acting on the behalf of shareholders, invests in risky and illiquid loans L_t funding this investment with fully insured short-term deposits B_t and equity E_t. The bank provisions for loan losses and, thus, holds loan loss reserves R_t. The bank's balance sheet at the beginning of period t is given by

Bank's Balance Sheet

Assets	Liabilities
L_t	B_t
$-R_t$	E_t

Following the accounting practice loan loss reserves are recorder on the asset side with a minus sign (contra asset account). Thus, the following balance sheet identity holds

$$L_t - R_t = B_t + E_t. \tag{1}$$

Aggregate State

The bank operates in the economic environment characterized by an aggregate state which is denoted by s_t. The aggregates state follows a discrete-time Markov chain. s_t can take a value g or b which corresponds to a good aggregate state (i.e., expansion) and a bad aggregate state (i.e., contraction), respectively. When the current aggregate state is i, the transition probability to state j next period is denoted by $q_{i,j} = \mathbb{P}(s_{t+1} = j | s_t = i)$ for $i, j \in \{g, b\}$.

Loan Portfolio

At the start of period t the bank has L_t outstanding loans. The loans are risky in that at the beginning of period t a random fraction $\xi_t \in [0,1]$ of them defaults. The cumulative distribution function of default rate ξ_t depends on the aggregate state and is given by $F(\xi_t; s_t)$. Thus, conditional on aggregate state ξ_t is iid. We further assume that the cdf is ranked in terms of first-order stochastic dominance with respect to aggregate state such that $F(\xi_t; s_t = g) \leq F(\xi_t; s_t = b)$.

After default rate has been realized, the bank obtains contractual interest payment $r^L_{s_t}$ on the fraction $(1-\xi_t)$ of non-defaulted loans, whereas the fraction ξ_t of defaulted loans repays $1-\lambda_{s_t} \in [0,1]$. Therefore, λ_{s_t} is a loss given default (LGD). Defaulted loans are written off during the same period they defaulted.[6]

Next, a constant fraction $\delta \in (0,1)$ of non-defaulted loans matures repaying the principal.[7] The bank then originates new loans, N_t. Negative values of N_t are associated with the bank closing or selling its loans. Therefore, the next period stock of loans is given by

$$L_{t+1} = L_t (1-\xi_t)(1-\delta) + N_t. \tag{2}$$

Readjusting the loan portfolio is a costly process.[8] Following De Nicolò et al. (2014) and Mankart et al. (forthcoming), the cost of readjusting loan portfolio is captured by an increasing and convex function $C : N_t \to \mathbb{R}$, that is $C'(N_t) > 0$ and $C''(N_t) > 0$.

Deposits and Deposit Insurance

The bank's debt consists of one-period deposits B_t. Since the average maturity of loans is $1/\delta > 1$ the bank is engaged in maturity transformation. Even though the bank faces a maturity mismatch on its balance sheet, we abstract from liquidity problem.[9] The bank can freely readjust

[6]Assuming that a loan defaulted during period t is resolved and is written off by the end of period t implies that the bank does not accumulate NPLs. This assumption greatly simplifies the analysis of our model without much affecting the main results since, as it will be discussed later in the paper, the incurred and expected loss approaches treat NPLs in the same way.

[7]This is consistent with an assumption of random loan maturity such that every period a loan matures with probability δ. The average maturity of the loan portfolio is then given by $1/\delta > 1$.

[8]For example, the screening cost of processing new loan applications or the cost associated with selling/closing outstanding loans.

[9]Liquidity considerations would bring an additional layer of complexity to our model without providing many benefits. The focus of our analysis is the effect of the provisioning requirement on bank lending. The interaction of provisioning requirement and liquidity issues is unlikely to be of the first-order importance provided that deposits

its level of deposits subject to the minimum capital regulation and provisioning requirement.[10]

We assume that deposits are fully insured with the deposit insurance priced at a flat rate which is normalized to zero. When the bank fails it defaults on deposits and their interest. In that case, the deposit insurance agency fully repays the depositors the principal and interest. Therefore, although from the point of view of the insurance agency deposits are risky, from the point of view of depositors these are risk-free claims.

Provisioning Requirement

Similar to Abad and Suarez (2018), we assume that the provisioning requirement is given by the requirement on loan loss reserves. The provisioning requirement stipulates that the bank must maintain loan loss reserves proportional to the entire portfolio of loans, that is

$$R_{t+1} = \theta_{s_t} L_{t+1}. \tag{3}$$

where $0 \leq \theta_{s_t} < 1$. Therefore, after the next period stock of loans, L_{t+1}, has been determined, the bank makes provisions to ensure that the above constraint is satisfied.

Equation (3) implies that the bank provisions exactly θ_{s_t} for a marginal loan. Thus, we refer to θ_{s_t} as a (marginal) provisioning rate.

Profits and Corporate Tax

The bank's profits are given by loan repayments less interest expense, operating expense, loan losses, and provisioning, that is

$$\begin{aligned}\pi_t :=& \pi\left(L_t, B_t, N_t, R_{t+1}, R_t, \xi_t, s_t, s_{t-1}\right) \\ =& r_s^L(1-\xi_t)L_t - rB_t - C(N_t) - \xi_t\lambda_{s_t}L_t - (R_{t+1} - R_t) - \iota.\end{aligned} \tag{4}$$

The first term in equation (4) is the repayment on non-defaulted loans. The second term is the interest expense on deposits. The third term is the loan adjustment costs associated with new

are fully insured.

[10] An alternative but equivalent assumption would specify a fixed amount of deposits D_t and a one-period risk-free debt S_t, such that $S_t + D_t = B_t$. To ensure that S_t is risk-free one would need to impose a collateral constraint à la Hennessy and Whited (2007). However, for large enough D_t a collateral constraint will always be slack and S_t will only be limited by the minimum capital constraint.

loans. The fourth term is the loan loss (write-off) minus recovery. The fifth term is the change in the loan loss reserves. Finally, the last term, a constant ι, is the fixed cost of running the bank.

The bank's profits are subject to corporate taxes. We follow Hennessy and Whited (2007), who proposes a parsimonious approach to model a corporate tax schedule which takes into account loss imitations. Loss limitations are introduced as a kink in the tax schedule. Specifically, when the taxable income, π_t, is positive the bank is subject to a tax rate τ^+, whereas when the bank's taxable income is negative the tax rate is given by $\tau^- \leq \tau^+$. Thus, τ^- is the rebate rate which is provided by the fiscal authority when the bank has negative taxable income. Therefore, the corporate tax rate is a function of the bank's profits and is given by

$$\tau(\pi_t) = \tau^+ \mathbb{I}_{\pi_t > 0} + \tau^- (1 - \mathbb{I}_{\pi_t > 0}), \tag{5}$$

where $\mathbb{I}_{\pi_t > 0}$ denotes an indicator functions which is equal to one when $\pi_t > 0$ and zero otherwise. Therefore, the bank's net income, that is after-tax profits, is is given by $(1 - \tau(\pi_t))\,\pi_t$.[11]

Equity

The bank's after tax profits are either paid out as dividends or retained to increase the stock of equity. Let X_t be a dividend pay-out, then the bank's book equity evolves according to the following accounting identity

$$E_{t+1} = E_t - X_t + (1 - \tau(\pi_t))\,\pi_t. \tag{6}$$

Negative values of X_t imply that the bank is raising external equity rather than paying out dividends. We assume that raising external equity is costly. This cost reflect the direct transactional costs (e.g. underwriter fees (Altınkılıç and Hansen (2000))) and indirect costs of raising external equity (i.e. debt overhang (Myers (1977) and Admati, DeMarzo, Hellwig, and Pfleiderer (2018)) or signaling issues (Myers and Majluf (1984))). Indirect costs do not apply if banks retain earnings (in line with pecking order theories).

Following Hennessy and Whited (2007), the cost of raising external equity is modeled in a reduced form. In particular, for every dollar raised in terms of equity the bank will have to pay

[11] If however, provisions for future losses are not tax deductible than net income is given by $(1 - \tau(\pi_t))\,\pi_t - \tau(\pi_t)(R_{t+1} - R_t)$. We proceed under the assumption that the provisions are tax-deductible and state it explicitly when it is not the case.

$1 + \eta^1_{s_t}$, where $\eta^1_{s_t} > 0$ is a variable component, and a fixed cost $\eta^0_{s_t} > 0$. Therefore, the cost of external equity is given by

$$\eta(X_t) := \left(-\eta^0_{s_t} + \eta^1_{s_t} X_t\right) \mathbb{I}_{X_t<0}, \tag{7}$$

where indicator function $\mathbb{I}_{X_t<0}$ is equal to 1 when $X_t < 0$, and 0 otherwise. Thus, $\eta(X_t)$ is negative when the bank raises equity and zero otherwise.

Capital Regulation

The bank operates in the regulatory environment characterized by the minimum capital regulation. The minimum capital regulation in our model serves to minimize the probability that the bank defaults, thus, minimizing the cost of the deposit insurance. Every period t, the bank's choice over the portfolio of loans and equity must satisfy the following minimum capital constraint

$$E_{t+1} \geq \kappa_{s_t} L_{t+1}, \tag{8}$$

where $\kappa_{s_t} \in [0, 1]$. The current regulatory regime (i.e., Basel III) is the one with risk-based capital requirements. Therefore, κ_{s_t} is an increasing function of loan default probability. We present the exact formula for κ_{s_t} in section 5.

Optimization Problem

There is no conflict between the bank's manager and shareholders. Thus, the manager maximizes the present value of all future dividends.[12] The effective control variables are the next period stock of equity, E_{t+1}, and loans, L_{t+1}. The choice over these controls, in turn, determines the bank's dividend payout, X_t, and lending, N_t.

For better intuition, it is useful, however, to restate the bank's control variables slightly. Rather then deciding on next period stock of equity, we let the bank to set next period voluntary capital buffer which is defined as

$$\Omega_{t+1} = \frac{E_{t+1}}{L_{t+1}} - \kappa_{s_t}. \tag{9}$$

[12]It is easy to show that in our model maximizing the present value of future dividends is equivalent to maximizing the present value of the future free cash flows to equity.

Mathematically this leads to the identical problem since for a given level of loans there is a one-to-one relationship between the stock of equity and voluntary capital buffer. The minimum capital constraint (8) then implies a non-negativity restriction on voluntary capital buffer, that is

$$\Omega_{t+1} \geq 0. \tag{10}$$

Formally, let $\Xi_t := [L_t, \Omega_t, \xi_t, s_t, s_{t-1}]$ denote the vector of state variables. Further, let the maximized present value of future dividends as a function of state vector be given by $V(\Xi_t)$, then the Bellman equation associated with the bank's maximization problem is given by

$$\begin{aligned} V(\Xi_t) = & \max_{\{\Omega_{t+1}, L_{t+1}\}} \left\{ 0, X_t + \eta(X_t) + \beta \mathbb{E}\left[V\left(\Xi_{t+1}\right) | s_t \right] \right\}, \\ \text{subject to} \quad & a) \;\; \Omega_{t+1} \geq 0, \\ & b) \;\; L_t - R_t = B_t + \left(\Omega_t + \kappa_{s_{t-1}}\right) L_t \\ & c) \;\; \left(\Omega_{t+1} + \kappa_{s_t}\right) L_{t+1} = \left(\Omega_t + \kappa_{s_{t-1}}\right) L_t - X_t + \left(1 - \tau(\pi_t)\right) \pi_t, \\ & d) \;\; L_{t+1} = L_t \left(1 - \xi_t\right) \left(1 - \delta\right) + N_t, \\ & e) \;\; \pi_t = r_s^L (1 - \xi_t) L_t - r B_t - C(N_t) - \xi_t \lambda_{s_t} L_t - (R_{t+1} - R_t) - \iota, \\ & f) \;\; R_{t+1} = \theta_{s_t}^L L_{t+1}, \end{aligned} \tag{11}$$

where constraints a) is the non-negativity constraint on the voluntary capital buffer (implied by the minimum capital constraint), b) the balance sheet identity, c) the law of motion for book equity, d) the law of motion for the stock of performing loans, e) the definition of profits before taxes, f) the definition of loan loss reserves (i.e., the provisioning requirement).

The solution to the problem in (11) is the policy functions $\Omega^*_{t+1} : \Xi_t \to \mathcal{R}_+$ and $L^*_{t+1} : \Xi_t \to \mathcal{R}_+$ which satisfy the above system. Default takes place at time t when the corresponding maximized value of equity $X_t + \eta(X_t) + \beta \mathbb{E}\left[V\left(\Xi_{t+1}\right) | s_t\right] < 0$.

4 Analysis of Optimal Policies

Although our model cannot be solved in closed form, a great deal of intuition can be derived from the first-order conditions of the optimization problem (11). First, we proceed with the analysis of the bank's optimal capital policy and then we turn to the optimal lending policy.

4.1 Optimal Voluntary Capital Buffer

Using the envelope theorem, the first order condition with respect to Ω_{t+1} of the optimization problem (11) is given by

$$\left(1+\eta^1_{s_t}\mathbb{I}_{X_t<0}\right)=\lambda_t+\beta\mathbb{E}_t\Big[\left(1+\eta^1_{s_t}\mathbb{I}_{X_{t+1}<0}\right)\left(1+\left(1-\tau\left(\pi_{t+1}\right)\right)r\right)\Big]. \tag{12}$$

where λ_t is the Lagrange multiplier associated with the non-negativity constraint on Ω_{t+1}. $\mathbb{I}_{X_t<0}$ is the indicator function equals 1 when $X_t<0$ and zero otherwise. Finally, the expectation is conditional on current aggregate state of the economy, that is $\mathbb{E}_t[.]:=\mathbb{E}[.|s_t]$.

To interpret (12), we follow Hennessy and Whited (2005) and Strebulaev and Whited (2012) assume that the bank follows a given lending policy, that is, L_{t+1} is fixed. Thus all of the terms in the above equation are constant, except for those involving Ω_{t+1}. Intuitively, Increasing voluntary capital buffer is accomplished either via profit retention or through external equity issuance. Thus, it either reduces dividends or increases equity issuance during the current period. However, the increased buffer can then be used to offset loan losses next period which would either increases dividends or decreases equity issuance.

The left-hand side of (12) captures the marginal cost associated with increasing the voluntary capital buffer. When the buffer increased through profit retention the marginal cost is 1, whereas increasing the buffer via external equity issuance increases this cost to $(1+\eta^1_{s_t})$. Intuitively, increasing voluntary capital buffer is costlier when it is built via costly external equity issuances.

The right-hand side of (12) captures the expected marginal benefit of increasing voluntary capital buffer. First, for a given lending policy increasing voluntary capital buffer relaxes the non-negativity constraint. Second, a higher voluntary capital buffer improves the bank's loss absorption capacity, thus, either increasing the next period dividends or reducing a costly equity issuance. Finally, a higher voluntary buffer implies lower leverage which reduces debt interest expense. The future marginal benefit is further multiplied by $\left(1+\eta^1_{s_t}\mathbb{I}_{X_{t+1}<0}\right)$ reflecting its higher value in those states of the world in which the bank must raise costly external equity.

For the bank to hold a strictly positive voluntary buffer, that is $\Omega_{t+1}>0$, two conditions need to be met. First, the cost of raising equity externally is high ($\eta^0_{s_t}$ or $\eta^1_{s_t}$ are sufficiently large). Second, the potential loan loss should be large (ξ_{t+1} can take relatively large values). Intuitively, the benefit of a voluntary capital buffer is that it provides insurance against having to raise costly external equity. This insurance is important only when raising external equity is both costly and likely enough.

Moreover, it is straightforward to argue that the optimal voluntary buffer is decreasing in κ_{s_t} and θ_{s_t}. Intuitively, increasing either κ_{s_t} or θ_{s_t} improves the bank's loss absorption capacity which lowers the likelihood of having to recapitalize. As a result, the value of voluntary capital buffer declines and the bank optimally holds less equity in excess of the required minimum.

4.2 Optimal Lending Policy

Next, we analyze the optimal lending policy. The first order condition with respect to L_{t+1} of the optimization problem (11) is given by

$$\begin{aligned}\left(1+\eta^1_{s_t}\mathbb{I}_{X_t<0}\right)\left((1-\tau(\pi_t))\left(C'\left(N_t\right)+\theta_{s_t}\right)+\kappa_{s_t}+\Omega_{t+1}\right)=\beta\mathbb{E}_t\Big[\left(1+\eta^1_{s_t}\mathbb{I}_{X_t<0}\right)\left((1-\tau(\pi_{t+1}))\right.\\ \left(r^L_{s_{t+1}}(1-\xi_{t+1})+\theta_{s_t}-\lambda_{s_{t+1}}\xi_{t+1}-rB_{t+1}/L_{t+1}+C'\left(N_{t+1}\right)(1-\delta)(1-\xi_{t+1})\right)+\kappa_{s_t}+\Omega_{t+1}\Big)\Big].\end{aligned} \tag{13}$$

To interpret equation (13), we again suppose that the optimal decision over the next period voluntary capital buffer, Ω_{t+1}, has already been made. Therefore, all terms in equation (13) are constant, except for those involving L_{t+1}. The left-hand side of equation (13) is the present net cost of originating an additional loan, whereas the right-hand side is its discounted expected net benefit.

For provide a better intuition behind the intertemporal trade-off for a marginal loan, the left- and right-hand sides of (13) can be rewritten to disentangle the effects that come from the marginal loan's cash flows and the minimum capital regulation. The left-hand side of (13) is then given by

$$\left(1+\eta^1_{s_t}\mathbb{I}_{X_t<0}\right)\Big[\,(1-\tau(\pi_t))\,C'\left(N_t\right)-\tau(\pi_t)\theta_{s_t}+(\theta_{s_t}+\kappa_{s_t}+\Omega_{t+1})\,\Big] \tag{14}$$

The first two terms in brackets are the current cash flows associated with originating an additional loan which are the after-tax direct cost of originating the loan, $(1-\tau(\pi_t))\,C'(N_t)$, and the tax shield from provisioning θ_{s_t} for a marginal loan, respectively. The third term captures the cost of capital regulation which restricts the bank's free cash flow to equity via the minimum capital requirement, thus, either decreasing dividends or increases the required equity injection. This term reflects the fact that the bank holds $\kappa_{s_t} + \Omega_{t+1}$ in equity, and θ_{s_t} in provisions. When the resulted free cash flow to equity is negative, $X_t < 0$, the bank is raising external equity and the above term is multiplied by $1 + \eta^1_{s_t}$.

In a similar way, the right-hand side of (13), which constitute the next period expected benefit of a marginal loan, can be re-written as

$$\beta \mathbb{E}_t \Bigg[\left(1 + \eta^1_{s_t} \mathbb{I}_{X_t<0}\right) \Bigg((1 - \tau(\pi_{t+1})) \left(r^L_{s_{t+1}} (1 - \xi_{t+1}) - r B_{t+1}/L_{t+1} + C'\left(N_{t+1}\right)(1-\delta)(1-\xi_{t+1}) \right) \\ + \tau(\pi_{t+1})(\lambda_{s_{t+1}}\xi_{t+1} - \theta_{s_t}) + (\theta_{s_t} + \kappa_{s_t} + \Omega_{t+1} - \lambda_{s_{t+1}}\xi_{t+1}) \Bigg) \Bigg]. \tag{15}$$

The first and second terms inside the large parenthesis are the future cash flows associated with the marginal loan. The first term accounts for the contractual repayment in the case of no loan default, the expense associated with debt financing of the loan, and the reduced cost of originating a new loan in there future (provided the original loan nether matures nor defaults). The second term is the cash flow associated with a tax break on capital loss. Since the loss of θ_t on the marginal loan was already recognized at the time of its inception the bank may only claim the loss of $\lambda_{s_{t+1}}\xi_{t+1} - \theta_{s_t}$. Should the bank have over provisioned for the loan, $\theta_t > \lambda_{s_{t+1}}\xi_{t+1}$, the bank becomes liable to pay the tax of $\tau(\pi_{t+1})(\theta_{s_t} - \lambda_{s_{t+1}}\xi_{t+1})$.

Finally, the last term inside the large parenthesis of (15) captures the benefit of equity and provisions. Both provide a cushion to accommodate the realized loss of $\lambda_{s_{t+1}}\xi_{t+1}$, thereby, increasing the next period's dividends or reducing the required equity injection.

Our analysis of equation (13) suggests that the provisioning requirement for future losses affects lending in a similar way to the minimum capital requirement. The following proposition formalizes this similarity.

Proposition 1. *Let Ξ_t denote the current state of the bank, that is $\Xi_t = [L_t, \Omega_t, \xi_t, s_t, s_{t-1}]$. Further, let $L^*_{t+1}(\Xi_t)$ be the optimal lending policy of the bank which is subject to the minimum capital requirement $E_{t+1} \geq \kappa_{s_t} L_{t+1}$ and the provisioning requirement $R_{t+1} = \theta_{s_t} L_{t+1}$. Then $L^*_{t+1}(\Xi_t)$ is the optimal lending policy of the bank which is subject to the minimum capital requirement $E_{t+1} \geq (\kappa_{s_t} +$*

$\theta_{s_t})L_{t+1}$, the provisioning requirement $R_{t+1} = 0$, and receives a tax subsidy $\tau(\pi_t)\,(\theta_{s_t}L_{t+1} - \theta_{s_{t-1}}L_t)$ every period t.

Proof. It is straightforward to show that the first-order condition with respect to L_{t+1} of the optimization problem (11) in which the minimum capital requirement κ_{s_t} is replaced with $\alpha_{s_t} = \kappa_{s_t} + \theta_{s_t}$ and the tax subsidy $\tau(\pi_t)\,(\theta_{s_t}L_{t+1} - \theta_{s_{t-1}}L_t)$ is added to the net income is given by equation (13). □

Proposition 1 implies that the effect of the provisioning requirement on bank lending can be viewed through two channels. The first channel is due to the fact that the minimum capital regulation is implemented in terms of book values. Accounting-wise the net income before provisions is the source for both equity capital (through retention) and loan loss reserves (through provisioning). Thus, increasing provisions limits the bank's ability to increase equity through retention and vice versa. Moreover, when the bank does not have enough internal funds for either provisions or equity it will have to make up for it by raising external equity. Therefore, the cost of provisions is the same as that of equity. At the same time, the benefits are the same too as both loan loss reserves and equity capital serve as a buffer to absorb the losses from outstanding loans when those are realized.

The second channel through which provisioning requirement has a real effect of bank lending is due to the tax-deductibility of provisions. As an expense, provisions are tax-deductible and, thus, generate a tax break which in turn affects the bank's intertemporal trade-off.

An important insight from Proposition 1 is that the provisioning requirement and the minimum capital requirement are in effect the two sides of the same coin. When provisions are not tax-deductible, increasing the provisioning requirement has *exactly* the same effect on the optimal lending decisions of the bank as that of increasing the capital requirement. This insight informs the policy debate around macro- and micro-prudential regulation that capital requirements (set by bank regulators) and accounting standards on provisioning (set by market regulators) cannot be isolated from each other. Moreover, the tax treatment of provisions will also influence the optimal lending policies. This has important policy implications, especially given that both the accounting standards for loan loss recognition and the capital regulation under Basel III are undergoing drastic modifications. In the following section, we discuss the effect of a provisioning requirement on bank lending via these two channels in detail.

4.3 Provisioning Requirement, Bank Lending, and Stability

Provisioning Requirement and the Capital Regulation Channel

First, we discuss the effect of a provisioning requirement on bank lending and stability that comes from the capital regulation channel. For the time being, we, therefore, assume that provisions are not tax-deductible. The capital regulation channel of a provisioning requirement is active only when the bank is subject to the minimum capital regulation (formulated in terms of book values). When instead the bank's leverage is constrained in terms of market values (by market forces, for example), a provisioning requirement will not have any real effect on lending or stability unless provisions are tax-deductible. Since equity and accumulated provisions provide the same loss absorption capacity it is not essential how the bank allocates its loss absorption capacity between equity and loan loss reserves.[13]

When the bank, however, is subject to a minimum capital regulation in terms of book values, having to recognize a future loss of $\theta_{s_t} L_{t+1}$ in a current period implies that the bank effectively operates under the minimum capital requirement given by $E_{t+1} \geq (\kappa_{s_t} + \theta_{s_t}) L_{t+1}$. Therefore, under this channel, the effect of the provisioning requirement on bank lending and stability can be fully understood in terms of the minimum capital requirement. For example, forcing higher provisions, that is increasing θ_{s_t}, strengthens the bank's loss absorption capacity and, thus, improves bank stability. At the same time, it reduces loan supply by making lending more expensive as it effectively constrains the bank's leverage, thereby, reducing the bank's ability to rely on a cheaper source of financing such as deposits.

However, the cyclical effect of increasing θ_{s_t} on lending depends on how this increase is implemented over the cycle, that is how it is distributed between θ_g and θ_b. For example, increasing θ_g while holding θ_b fixed forces the bank to hold more capital during good times and thus is equivalent to adopting a procyclical capital requirement similar to that of Basel III (i.e., countercyclical cap-

[13]Lifting the capital requirement in our model would imply that the bank is no longer constrained in its optimal choice of leverage ratio, since in this case $\Omega_{t+1} = \frac{E_{t+1}}{L_{t+1}}$. As such, forcing the bank to hold larger reserves would lead to the bank lowering Ω_{t+1} one-for-one to an increase in θ_{s_t} such that there will be no real effect on lending or stability (with fully insured deposits and no minimum capital requirement nothing prevents the bank from operating under a negative value of Ω_{t+1} which would then mean a negative book value of equity). From the market point of view, the effective leverage ratio will be given by $\theta_{s_t} + \Omega_{t+1}$.

ital buffers).[14] The benefits of such a time-varying macroprudential policy in terms of mitigating lending procyclicality are well understood theoretically (e.g., Repullo and Suarez (2012), Begenau (2019)) and supported empirically (Jiménez et al. (2017)).

In contrast, tightening the bank's capital requirement in a contraction, that is increasing θ_b while holding θ_g fixed is equivalent to adopting a more countercyclical capital requirement, and thus quite intuitively delivers the opposite result.[15] Such a policy magnifies the on-impact response of the bank's profits to the arrival of a contraction and puts an additional strain on the bank's lending capacity during bad times which amplifies lending procyclicality.

Provisioning Requirement and the Tax-Deductibility Channel

Even when the bank is not subject to the minimum capital regulation, provisioning requirement for future losses will have a real effect on lending and stability provided that provisions are tax-deductible. From Proposition 1, when provisions are tax-deductible the bank enjoys a tax subsidy

$$\tau\left(\pi_t\right)\left(\theta_{s_t} L_{t+1} - \theta_{s_{t-1}} L_t\right).$$

To better understand the effect of this subsidy on bank lending, we write its value for a marginal loan as

$$\tau\left(\pi_t\right)\left(1+\eta^1_{s_t}\mathbb{I}_{X_t<0}\right)\theta_{s_t} - \beta\mathbb{E}_t\left[\tau\left(\pi_{t+1}\right)\left(1+\eta^1_{s_t}\mathbb{I}_{X_{t+1}<0}\right)\right]\theta_{s_t}. \tag{16}$$

The first term is the present tax benefit of provisioning for the marginal loan. Provisioning θ_{s_t} for the marginal generates a cash flow of $\tau\left(\pi_t\right)\theta_{s_t}$ either increases current dividend or lowers a required equity issuance. In the latter case this cash flow is more valuable since it lowers the cost associated with raising costly external (thus multiplied by $\left(1+\eta^1_{s_t}\mathbb{I}_{X_t<0}\right)$). The second term is the expected marginal cost associated with the tax deductibility of provisions. Provisioning θ_{s_t} for a marginal loan lowers the tax subsidy next period which either decreases future distributions or increase external equity issuance. Intuitively, by provisioning for future losses the bank is able to

[14] We follow the common terminology that procyclical capital requirements result in countercyclical capital buffers that are meant to reduce the procyclicality of credit by banks. See Borio (2003), Hanson, Kashyap, and Stein (2011), and Jiménez, Ongena, Peydró, and Saurina (2017).

[15] For example, Repullo and Suarez (2012) theoretically examine the procyclical effect of the Basel II capital regulation. Due to its risk-weight approach, Basel II effectively imposed a countercyclical capital requirement thereby increasing the correlation of lending with the cycle.

reduce it current taxable income by claiming higher loss. However, when next period the realized losses are less than what was already recognized (i.e., when the bank over-provisions) the bank ends up paying are a higher tax bill.

In general, the tax-deductibility of provisions increases lending as it generates additional cash flow. At the same time, its effect on the cyclicality of loan supply and stability depends on the design of the tax-schedule $\tau(\pi_t)$. When the loss limitations are relatively large, that is $\tau^+ >> \tau^-$ making provisions tax-deductible increases lending procyclicality. Intuitively, $\tau^+ >> \tau^-$ implies that at the margin the subsidy is more valuable in good times than in bad. As such the bank tries to optimize with respect to the subsidy by lending more in good times and less in bad. As a consequence of increased lending procyclicality, the tax-deductibility of a provisioning requirement may harm stability.

However, relaxing loss limitations (i.e., increasing the rebate rate τ^-) can help to mitigate the procyclical effect of the tax deductibility. Intuitively, increasing the rebate rate makes increasing the tax subsidy on a marginal loan in a contraction. This makes lending in a contraction more profitable and thus the bank readjusts its optimal lending policy such that it originates more loans in bad times.

Provisioning for Incurred vs. Expected Credit Losses

Disentangling the effect of the provisioning requirement for future losses into the two channels discussed above is useful for understanding the potential impact of adopting the provisioning requirement based on an expected credit loss approach. In particular, the capital regulation channel of the provisioning requirement suggests that, although replacing the ILM with the ELM may improve bank stability, it may also result in a more procyclical supply of loans.

The ILM does not allow provisioning for losses that are expected to take place in the future. Only the losses incurred as of the balance sheet date, that is those that have been factually identified, can be recognized under the ILM. Under the ELM, however, on top of provisioning for incurred losses, the bank is also obliged to recognize expected losses over a specified horizon on the entire portfolio of loans.[16] Therefore, replacing the ILM with the ELM is equivalent to increasing provi-

[16]The exact specification of the provisioning requirement, that is θ_{s_t}, under the ILM and the ELM (IFRS 9 and new US GAAP) are presented in the next section.

sioning requirement, that is increasing θ_{s_t}. From the capital regulation channel of the provisioning requirement, this will increase stability, by providing an additional buffer, and reduce the supply of bank loans, by reducing lower leverage.

However, we argue that an important consequence of adopting the ELM is that it may also aggravate lending procyclicality. This is because replacing the ILM with the ELM increases required provisions relatively more in contractions than expansions. The defying feature of the ELM is that it employs the so-called Point-in-Time (PIT) probability of loan default in estimating expected credit losses. That is expected losses are estimated not just based on historical data but also with the incorporation of all presently available relevant information.[17] In terms of our model, this means that expected losses are estimated conditional on the aggregate state. However, when the bank lacks the capacity to anticipate the deterioration of the aggregate state, the PIT estimates of expected losses imply that the main bulk of these losses would be recognized *after* the start of a contraction and not before it. Therefore with the adoption of the ELM, θ_{s_t} becomes more procyclical which in turn implies that the bank operates under a more procyclical capital requirement under the ELM.

Furthermore, the procyclical effect of the ELM is likely to be further exacerbated via the tax channel. Unlike the prudential provisions of Basel III, the expected provisions under the ELM are accounting losses and, therefore, are tax-deductible.

Although from the microprudential point of view the ELM provides a benefit in terms of strengthening the bank's loss absorption capacity and, thus, improving bank stability, it may impose costs from the macroprudential point of view. An important objective of macroprudential policy is the control over the procyclicality of bank lending as increased procyclicality can lead to negative feedback loops on the evolution of the economy resulting in a more severe contraction (Hanson et al. (2011)). This objective has been addressed through such a time-varying macroprudential policy as countercyclical capital buffers of Basel III. Adopting ELM could, therefore, reduce the benefits of such policies by inducing more procyclicality.

[17]For example according the IFRS 9 "an entity shall adjust historical data, such as credit loss experience, on the basis of current observable data to reflect the effects of the current conditions and its forecasts of future conditions that did not affect the period on which the historical data is based and to remove the effects of the conditions in the historical period that are not relevant to the future contractual cash flows." paragraph B 5.5.52 in IASB (2014)).

5 Quantifying the Long-Term Effect of the Expected Loss Model

In this section, we calibrate our model to quantify the long-term effect of replacing the incurred loss approach to loan loss provisioning (i.e., ILM) with the forward-looking approach based on expected losses (i.e, ELM). We begin by discussing the calibration of the model and specify the provisioning requirements under the ILM and ELM. We then present the quantitative results implied by our model.

5.1 Calibration

5.1.1 Loan Default Rate Distribution

We assume that the bank's loan portfolio consists of two categories (types) of loans to which we refer as stage 1 (good credit quality) and stage 2 (impaired credit quality) loans.[18] All loans within the same category have identical default probability with (imperfectly) positively correlated defaults. Let ξ_t^i be the aggregate failure rate of category i loans such that the corresponding default probability is given by $p_{s_t}^i = \mathbb{E}[\xi_{t+1}^i | s_t]$. Furthermore, let ω_{s_t} denote a fraction of stage 1 loans in the bank's loan portfolio. Then using our previous notation it holds that the default rate for the portfolio of loans is given by

$$\xi_t = \omega_{s_t}\xi_t^1 + (1 - \omega_{s_t})\xi_t^2. \tag{17}$$

Following Repullo and Suarez (2012) we assume that the probability distribution of ξ_t^i is implied by the single common risk factor model of Vasicek (2002), which was adopted by the Basel approach to provide a value-at-risk foundation to the minimum capital requirements under Basel II and III.[19] Under this model the cumulative distribution function of ξ_t^i conditional on aggregate state is given by

$$F(\xi_t^i; s_t) = \Phi\left(\frac{\sqrt{1 - \rho_{s_t}^i}\,\Phi^{-1}\left(\xi_t^i\right) - \Phi^{-1}\left(p_{s_t}^i\right)}{\sqrt{\rho_{s_t}^i}}\right), \tag{18}$$

where $\Phi(.)$ is the standard normal cumulative distribution function and $\rho_{s_t}^i \in (0,1)$ is the loan default correlation parameter which captures the dependence of individual loan defaults on the

[18] The reason behind introducing this loan heterogeneity will become clearer when we specify the provisioning requirements under the ELM of IFRS 9 and the new US GAAP. In short, this is important to fully capture the mixed-horizon approach of ELM under IFRS 9.

[19] Under this specification the performance of an individual bank loan depends on a common factor and idiosyncratic factor. For more detail see Repullo and Suarez (2012).

common risk factor, thus, determining the degree of correlation between individual loan defaults. The correlation coefficient is computed based on the formula adopted in Basel III (2017), which is

$$\rho^i_{s_t} := \rho\left(p^i_{s_t}\right) = 0.12\frac{1-\exp^{-50p^i_{s_t}}}{1-\exp^{-p^i_{s_t}}} + 0.24\left(1-\frac{1-\exp^{-50p^i_{s_t}}}{1-\exp^{-p^i_{s_t}}}\right).$$

5.1.2 Provisioning Requirement

Provisioning Requirement under the Incurred Loss Approach

The ILM does not allow provisioning for credit losses which are based on the events expected to happen in the future. Under the incurred loss approach it is assumed that all loans will be repaid until the evidence to the contrary is established. Only at that point, the impaired loan (or portfolio of loans) can be written down to a lower value.

The provisioning rate for future losses under the ILM is given by $\theta^{ILM} = 0$. This is consistent with our assumption that the bank does not accumulate NPLs as bad loans are resolved and written down during the same period they default.[20]

Provisioning for Prudential Expected Losses under the Internal Ratings-Based (IRB) Approach

On top of provisioning for incurred losses under the ILM, the banks that follow the Internal Ratings-Based (IRB) approach are required to provision for prudential expected losses. These expected losses are based on the one-year horizon and are computed using the so-called Through-the-Cycle (TTC) default probabilities and a conservative (downturn) estimates of loss given default.[21] Specifically, under the IRB approach banks must subtract their one-year expected losses from available capital (as capital is meant to absorb the bank's unexpected losses over a year horizon). Therefore, the provisioning rate for loan category i under the IRB approach is given by

$$\theta^{IRB,i} = \mathbb{E}[\lambda^i_b \xi_{t+1}], \tag{19}$$

[20] The precise interpretation of $\theta^{ILM} = 0$ is as follows. At the beginning of period t, the bank receives objective evidence that $\xi_t L_t$ of outstanding loans will default. The bank then makes provisions for these incurred loans. Next, the bank resolves and writes down such loans removing them from its balance sheet. The bank enters the next period with no bad loans.

[21] Abad and Suarez (2018) provide a detailed discussion on this matter. The Through-the-Cycle (TTC) default probabilities correspond on unconditional default probabilities in our model and the downturn estimates of loss given default is given by λ^i_b.

which is the *unconditional* on the aggregate state mean of the loan loss rate. Provisioning for prudential losses of the IRB approach is not tax-deductible.[22]

Provisioning Requirements under the Expected Loss Model

We distinguish between two main provisioning approaches which are based on the expected loss approach: the Expected Credit Loss Model of IFRS 9 and the Current Expected Credit Loss (CECL) model of the new US GAAP. These two approaches are different in terms of the horizon of expected provisions. The IFRS 9 approach employs the mixed-horizon approach (one-year and lifetime discounted expected losses depending on loan credit risk), whereas the US GAAP approach adopts a lifetime horizon.

Under the expected provisioning, approach banks employ statistical inference to provide an unbiased estimate of their expected loan losses using the Point-in-Time (PIT) approach (i.e., conditional on the current state). Provisioning for expected losses then effectively sets the loan loss reserves to the expected discounted losses. In our analysis, we assume that the expected losses are estimated precisely in that the estimates are equal to the population moments. Second, we assume that misreporting is not possible.[23]

When the bank must provision for *one-year* discounted expected losses of loan category i then the provisioning rate is given by

$$\theta_{s_t}^{1Y,i} = \frac{1}{1 + d_{s_t}} \mathbb{E}[\lambda_{s_{t+1}^i} \xi_{t+1} | s_t], \tag{20}$$

where d_{s_t} is an appropriate discount rate (we discuss the choice of discount rate below).

When the bank must provision for *lifetime* discounted expected losses the provision rate is given by the following recursive formula

$$\theta_{s_t}^{LT,i} = \frac{1}{1 + d_{s_t}} \mathbb{E}[\lambda_{s_{t+1}}^i \xi_{t+1} + (1 - \xi_{t+1})(1 - \delta)\theta_{s_{t+1}}^{LT,i} | s_t] \tag{21}$$

[22]This means that the after-tax profit under the IRB approach is given by $(1 - \tau(\pi_t))\pi_t - \tau(\pi_t)(R_{t+1} - R_t)$.

[23]We do not claim that the ability to misreport expected losses is either not important or not possible. In fact, there is some empirical evidence consistent with that the banks that follow the IRB approach may underreport asset risk (Mariathasan and Merrouche (2014)). However, our goal is to assess the effect of the ELM under the "first-best" scenario without the additional complexity that comes from the imperfect regulatory enforcement.

We present the closed form solution for $\theta_{s_t}^{LT,i}$ in Appendix A.

Under the IFRS 9 the bank provisions one-year discounted expected losses for stage 1 loans and lifetime discounted expected losses for stage 2 loans. Therefore, the provisioning rate under IFRS 9 are given by

$$\theta_{s_t}^{IFRS9} = \omega_{s_t}\theta_{s_t}^{1Y,1} + (1 - \omega_{s_t})\,\theta_{s_t}^{LT,2}. \tag{22}$$

where the expected losses are discounted using the contractual repayment rate, that is, $d_{s_t} = r_{s_t}^L$.

Under new US GAAP, the banks will have to provision for the lifetime discounted losses of the entire loan portfolio. Therefore, the provisioning rate under the CECL is given by

$$\theta_{s_t}^{GAAP} = \omega_{s_t}\theta_{s_t}^{LT,1} + (1 - \omega_{s_t})\,\theta_{s_t}^{LT,2}, \tag{23}$$

where the expected losses are discounted using the risk-free rate, that is $d_{s_t} = r$.

5.1.3 Capital Requirement

To calibrate the minimum capital regulation parameter κ_{s_t}, we closely follow the approach from Repullo and Suarez (2012) and Abad and Suarez (2018). The empirical counterpart of the bank capital in our model is Tier 1 capital which primarily consists of common equity. Under the risk-based approach of Basel capital regulation κ_{s_t} is an increasing function of loan default probability. For the Internal-Ranking Based (IRB) approach the unexpected loss capital requirement for corporate and bank exposures is meant to ensure sufficient capital to cover loan losses with a confidence level of 99.9%. The formula for the unexpected loss capital requirement on stage i loan is given by

$$\nu_i = \left[\lambda_b \Phi\left(\frac{\Phi^{-1}(\bar{p}_i)}{\sqrt{1-\bar{\rho}_i}} + \sqrt{\frac{\bar{\rho}_i}{1-\bar{\rho}_i}}\Phi^{-1}(0.999)\right) - \bar{p}\lambda_b\right]\frac{1+(M-2.5)b_i}{1-1.5b_i}, \tag{24}$$

where $\bar{p}_i$ is the unconditional (on aggregate state) default probability of stage i loans, $\bar{\rho}_i = \rho(\bar{p}_i)$ is the unconditional loan default correlation coefficient of stage i loans, M is effective maturity in years (which in our model is given by $1/\delta$), and, finally, $b_i = [0.11852 - 0.05478\ln(\bar{p}_i)]$ is the maturity adjustment coefficient.[24] The overall capital requirement is then given by the weighted

[24]These formulas are taken from paragraph (53) of Internal Ratings-Based Approach for Credit Risk in Basel III (2017). For the IRB approach, Basel III specifies the use of downturn loss given default which in our model corresponds to λ_b and the through-the-cycle default probabilities which in our model correspond to unconditional default

average

$$\kappa_{s_t} = \omega_{s_t}\nu_1 + (1-\omega_{s_t})\nu_2.$$

One of the defining elements of Basel III is the Countercyclical Capital Buffer (CCyB). The CCyB is meant to reduce lending procyclicality by requiring the banks to hold and extra capital buffer during good times which can then be used to offset the increased losses when the aggregate state deteriorates. Specifically, under the CCyB the bank is required to hold the extra 2.5% of its Risk-Weighted Assets (RWA) in equity during an expansion. In our model, the CCyB is equivalent to increasing the capital requirement from κ_g to $1.3125\kappa_g$ in expansions.[25]

5.1.4 Parameter Values

Table 1 summarizes the values of the model parameters and Table 2 presents the calibrated value of the provisioning rates θ_{s_t} under the different provisioning approaches. In calibrating the aggregate process and the default distribution of loans, we follow closely Abad and Suarez (2018). We set the transition probability of remaining in the good state $q_{g,g} = 0.852$ and in the bad state $q_{b,b} = 0.5$. This implies that the average length of an expansion in our model is 6.76 years, whereas a contraction lasts on average for 2 years.[26]

Likewise, we set the default probability of a stage 1 loan to 0.54% and 1.9% conditional on expansion and contraction, respectively. The default probability of a stage 2 loan is 6.05% and 11.5% conditional on expansion and contraction, respectively. The fraction of stage 1 loans ω_{s_t} is 0.85 and 0.81 conditional on expansion and contraction, respectively. The average loan maturity is assumed to be 5 years for both loan categories which then implies that $\delta = 0.20$. Finally, the loss given default rates $\lambda^i_{s_t}$ for both loan categories are set to 0.4 and 0.3 conditional contraction and expansion, respectively.

Equation (24) then implies that the minimum capital requirement for stage 1 loans ν_1 is 0.085 and stage 2 loans ν_2 is 0.144. The overall capital requirement κ_{s_t} is given by 0.094 and 0.097 conditional on expansion and contraction, respectively.

probabilities $\bar{p}^i := q_g p^i_g + q_b p^i_b$.

[25] As per the Basel III's formula for RWA, in our model these are given by $RWA_t = \kappa_{s_{t-1}} 12.5 L_t$ at time t (see paragraph (53) of the section Internal Ratings-Based Approach for Credit Risk in Basel III (2017).). Therefore, the capital requirement conditional on an expansion increases from κ_g to $\kappa_g + 0.025 \times 12.5\kappa_g = 1.3125\kappa_g$ due to the CCyB.

[26] The unconditional probability of good and bad aggregate state are given by $q_g = (1-q_{b,b})/(2-q_{g,g}-q_{b,b}) = 0.77$ and $q_b = 1 - q_g = 0.23$, respectively.

Next, we following Mankart et al. (forthcoming), and set the interest on loan portfolio, $r^L_{s_t}$, to 4.89% and 5.34% conditional on contraction and expansion.[27] We set the risk-free rate to 1.8% and the discount factor β to 0.98.

As in Mankart et al. (forthcoming), we assume that the loan adjustment cost function $C(N_t)$ is quadratic, that is

$$C(N_t) = \phi N_t^2 \mathbb{I}_{\{N_t>0\}} + \phi\psi N_t^2 \mathbb{I}_{\{N_t<0\}} \tag{25}$$

where $\phi > 0$ and $\psi > 1$. The latter inequality reflects the fire-sale costs: selling/closing the loans is more expensive than originating them.

We calibrate the parameter from the loan adjustment cost function ϕ to match the volatility of loan growth in data. For the US economy, the volatility of annual loan growth rate is about 7-8%.[28] Calibrating this data moment we set $\phi = 0.50$. Following Mankart et al. (forthcoming), we also set $\psi = 1.3$ which implies a fire-sale discount of about 25%.

The fixed cost parameter ι is a parameter that allows us to control the level of the bank's profits such that they are not too high and, thus, the bank occasionally under the pressure to raise external equity. Furthermore, in our model, the bank holds voluntary capital buffer, $\Omega_t > 0$, only when equity issuance is sufficiently costly, that is $\eta^0_{s_t}$ and $\eta^1_{s_t}$ are large enough. Likewise, the magnitude of $\eta^0_{s_t}$ and $\eta^1_{s_t}$ matters for default probability since the bank may optimally decide to default rather than issue external equity when the latter is too costly. Finally, Dinger and Vallascas (2016) report that banks rarely issue equity during contraction and typically start issuing it when entering an expansion. We thus set $\iota = 0.0148$, $\eta^0_g = 0.0001$, $\eta^0_b = 0.01$, $\eta^1_g = 0.05$, $\eta^1_b = 0.24$, such that when our bank follows the ILM it on average holds a voluntary capital buffer of about 3%, which implies the CET1 ratio of about 10.5%, and, on average, faces the default probability of about 0.47%. Furthermore, due to a higher cost of raising external equity in a bad aggregate state, our bank seldom issue equity during a contraction but conditional on expansion the probability of equity issuance is about 3%.[29]

[27] Mankart et al. (forthcoming) report quarterly loan interest rates which are annualized in our analysis.

[28] Data source: FRED "Commercial and Industrial Loans, All Commercial Banks (CILACBQ158SBOG).

[29] Dinger and Vallascas (2016) estimate the annual probability of equity issuance of about 5.08% for a US bank using the data for 1993-2011. We calibrate this probability at a somewhat lower level in our model acknowledging the fact that unlike in the real world the balance sheet of our bank does not grow in the long run (due to stationarity of the model). Thus, our bank does not need to issue equity to support the long-run growth of its balance sheet. This inevitably implies a lower probability of issuing equity in our model.

Finally, the corporate tax rate τ^+ is set to 0.2. The corporate tax rebate rate τ^- is set equal to 0 in a benchmark calibration and 0.1 as in Hennessy and Whited (2007) when we explore the effect of taxes. To asses the results of our calibration, we report some relevant moments implied by our model (under the benchmark case of the ILM) and the corresponding real data moments in Table 3 (the details on the numerical approach of solving the model can be found in Appendix B). The model matches the data moments reasonably well even though the model has a rather parsimonious structure.

5.2 Effect on the Cyclicality of Lending and Default Probability

Table 4 summarizes the conditional and unconditional first moments of the bank's various endogenous variables and default probability under the ILM and ELM when expected provisions are tax-deductible. We also include the provisioning requirement implied by the Internal Ratings-Based (IRB) approach as an additional benchmark to compare with the two ELM models (IFRS 9 and US GAAP). The reported first moments and default probabilities are computed based on simulating the model for 40,000 periods with the first 200 observations excluded.

The results in Table 4 are consistent with our qualitative analysis in the previous section. The bank operating under the ELM (IFRS 9 or US GAAP) originates fewer loans, lends more procyclically, but, at the same time, is subject to a lower default probability than the bank under the ILM. In particular, unconditional on the aggregate state the bank following the ELM originates on average about 0.6%-0.8% fewer loans compared to that under the ILM. However, the difference in lending between the ELM and ILM is much more striking when we compare lending activity conditional on the aggregate state. In particular, conditional on a contraction the ELM bank originates on average as much as 6.8% - 7.8% fewer loans than the ILM bank. This highlights the strong procyclical effect of the ELM.

Table 4 further suggests that as far as lending is concerned adopting either IFRS 9 or the US GAAP has a rather similar effect. At first glance, this may seem surprising, because the provisioning requirement of the new US GAAP implies larger yet more procyclical provisioning rates than those under IFRS 9. Thus, one would expect that IFRS 9 should have a stronger negative effect on lending in contractions than the new US GAAP, whereas the new US GAAP should have a stronger negative effect on lending unconditional on the aggregate state. However, such logic does not take into account the endogenous adjustments in the bank's relatively large voluntary capital buffer which allows for smoothing of the effect of the ELM on lending. For example, we can see that under the new US GAAP the bank holds a lower voluntary capital buffer than under IFRS 9. This reflects the larger provisioning rates under the new US GAAP requirement. At the same time, under IFRS 9 the bank reduces its voluntary buffer conditional on a contraction relatively more than under the new US GAAP.[30] This allows the bank to better smooth the more countercyclical requirement of IFRS 9.

The lower levels of the voluntary capital buffers under the ELM is an intuitive result since larger loan loss reserves of the ELM reduce the benefit of holding voluntary capital buffer. Our qualitative analysis from the previous section suggests that the bank's stability improves with the increase in the provisioning requirement due to the capital regulation channel. This result, however, is conditional on that the provisions are not tax-deductible since the tax channel of the provisioning requirement can worsen the stability via amplifying the procyclicality of lending. Consistent with this reasoning, Table 4 suggest that, although the bank holds a lower voluntary capital buffer under the expected loss approach, it is still less likely to fail except in the case when IFRS 9 replaces the IRB approach (below we show that when expected provisions are not tax-deductible default rate decreases in this case as well). Furthermore, our results suggest that the expected loss model of the new US-GAAP achieves a better reduction in default probability than IFRS 9. There are two reasons for this result. First, the US-GAAP model implies larger provisions, and hence, larger loan loss reserves. Second, the provisioning requirement is less countercyclical than the one under IFRS 9. Note that the effect of replacing the ILM with the ELM on lending and stability is slightly less pronounced for the bank that follows the IRB approach since the increase in the level of required provisions for such a bank is relatively smaller.

Table 5 repeats the same exercise but under the assumption that expected provisions are not tax-deductible. The differences in the magnitudes of the results reported in Table 4 and Table 5, thus, help us to disentangle the effect of the tax channel. The impact on new loans when one changes from ILM to ELM is less pronounced when expected provisions are not tax-deductible. For

[30]This is consistent with the results in Abad and Suarez (2018) and Krüger et al. (2018) who suggest that IFRS 9 may have a more pronounced procyclical effect on bank capital than the new US GAAP. Our results suggest, that this more procyclical effect of IFRS 9 on capital does not necessarily translate into a more procyclical effect of lending due to endogenous voluntary capital buffers.

example, conditional on a contraction the bank which follows the ELM originates on average 5.3% - 6.2% fewer loans than that following the ILM. The effect on outstanding loans is also reduced as the bank following the ELM originating on average about 0.4%-0.7% fewer loans compared to that under the ILM. Furthermore, Table 5 confirms that the ELM achieves a better reduction in default rates when expected provisions are not tax-deductible. Finally, we note that the tax-deductibility of expected provisions plays an important role in whether the likelihood of raising external equity increases or decreases with the adoption of the ELM. Our analysis suggests that when expected provisions are (not) tax-deductible the bank is less (more) likely to raise external equity under the ELM than the ILM.

To further understand the effect of taxes, we explore the effect of replacing the ELM with the ILM when the bank faces reduced loss limitations. Table 6 reports the results of a similar exercise but this time expected provisions are tax-deductible and the bank also enjoys tax rebates, that is we increase τ^- from 0 to 0.1. Since now the bank also receives a subsidy when its profits are negative it has stronger incentives to lend in contractions. Table 6 suggests a relatively smaller procyclical effect of replacing the ILM with the ELM when the bank enjoys tax rebates. In particular, Table 6 reports that conditional on a contraction the bank following the ELMnow originates on average 4.0% - 5.9% fewer loans than under the ILM. Furthermore, consistent with our previous results, Table 6 suggests that the ability of the ELM to reduce failure rates improves with the increase in tax rebates.

Finally, we examine the effect of replacing the ILM with the ELM when the bank is subject to the Countercyclical Capital Buffer (CCyB). The CCyB is one of the defining features of Basel III and is meant to reduce lending procyclicality by requiring the banks to hold some extra capital during good times which can then be used to smooth lending when a contraction arrives.[31] It is therefore important to examine whether the procyclical effect of the expected provisioning approach is partially mitigated by the CCyB. Table 7 summarizes the results.

Table 7 suggests that, although the introduction of the CCyB indeed helps to reduce lending procyclicality, the consequent replacement of the ILM/IRB with the ELM fully offsets this effect resulting in a more procyclical supply of loans. For example, unconditional on the aggregate state

[31] Under the CCyB that the bank is required to hold the extra 2.5% of its Risk-Weighted Assets (RWA) in equity during an expansion.

the bank following the ELM and holding the CCyB originates on average about 1.2%-1.6% fewer loans compared to that under the ILM/IRB without the CCyB requirement. But conditional on a contraction the bank subject to the ELM and the CCyB still originates on average 5.0% - 6.7% fewer loans than the ILM/IRB bank. Furthermore, when the bank is subject to the CCyB, we find that the IFRS 9 exhibits more procyclicality than the new US GAAP. For example, conditional on a contraction the bank that follows IFRS 9 and CCyB originates 6.7% (5.93%) fewer loans than that following the ILM (IRB), whereas the same number for the bank following the new US GAAP and CCyB is 5.75% (4.98%). This result is in line with our earlier discussion. The CCyB constraint reduces the bank's voluntary capital buffer which makes the effect of ELM more pronounced. With a smaller voluntary capital buffer, the bank is more restricted in its ability to absorb the cyclical variation of the provisioning requirement under IFRS 9. As a result, IFRS 9 has a more procyclical effect on lending. Due to the same reason, the provisioning requirement under the new US GAAP has a slightly more pronounced effect on the unconditional level of lending.[32]

5.3 Effect of the Arrival of a Contraction

Next, to better understand the procyclical effect of the ELM on bank behavior, we examine the average dynamic (multi-period) response of the bank's lending (N_t and L_t) and voluntary capital buffer Ω_t to the arrival of a contraction. To that end, we employ the impulse response analysis similar to that used in macroeconomic literature. In particular, we examine the evolution of the bank's lending and capital buffer decisions after the arrival of a contraction at $t = 0$, that is $s_0 = b$. Prior to $t = 0$ the bank is assumed to be in the expansionary aggregate state, that is $s_{-1} = g$, and the bank's endogenous state, that is the pair (L_0, Ω_0), is given by the respective unconditional means, that is $L_0 = \mathbb{E}[L_t]$ and $\Omega_0 = \mathbb{E}[\Omega_t]$. Given these initial values, we simulate 250,000 paths of N_t, L_t and Ω_t for T periods each. Then by taking a cross-sectional average of these paths produces the average response of N_t, L_t and Ω_t to the arrival of a contraction at $t = 0$. We refer to these average responses as (generalized) impulse response functions. The details on how the generalized impulse

[32] We note a rather modest effect of the CCyB on bank lending and stability. The CCyB reduces bank lending on average by about 0.23% and 0.56% under the ILM and IRB, respectively. At the same time, it increases new loans in a contraction only by about 0.12% and 0.65%, respectively. The effect on failure rates is relatively small too. Intuitively, this modest effect of the CCyB comes from the fact that it is mostly absorbed by the bank's voluntary capital buffer. From Tables 4 and 7 the CCyB substantially reduces the voluntary buffer as a natural response to having to hold an extra capital in good times.

responses are constructed can be found in Appendix B.

Figure 1 depicts the impulse response functions of new loans, outstanding loans, and the voluntary capital buffer to the arrival of a contraction at $t = 0$. The following scenarios are considered: when the expected provisions are tax-deductible (Panel A), when the expected provisions are not tax-deductible (Panel B), when the expected provisions are tax-deductible and the bank loss limitations are reduced by setting $\tau^{-} = 0.1$ (Panel C), and finally when the expected provisions are tax-deductible and the bank is subject to the CCyB constraint (Panel D). The impulse response functions are depicted for the ILM, IRB, IFRS 9, and the new US GAAP cases. Finally, the impulse response functions for new and outstanding loans are depicted in terms of relative deviations from unconditional means, whereas for the voluntary capital buffer these are in levels.

Our model predicts a much stronger on-impact reaction of new loans to the arrival of a contraction under both IFRS 9 and US-GAAP than under the ILM. Under IFRS 9 and US-GAAP new loans fall by about 27% at the onset of a contraction when the expected provisions are tax-deductible. The corresponding drop under the ILM and IRB approach is only about 16.5%. These suggest that bank lending under the expected loss approach is characterized by a stronger degree of procyclicality. Figure 1 also shows a substantially more abrupt and deeper decline and a slower recovery of total loans under the expected approach. This dynamics of the outstanding loans under the ELM reflects the large on-impact reaction of new loans to the arrival of a contraction. Modifications such as not allowing the tax-deductibility of the expected provisions, relaxing loss limitations, or introducing the CCyB, all help to reduce this on-impact reaction as seen from the Panels B, C, and D of Figure 1.

Finally, Figure 1 also shows that voluntary capital buffer exhibits a rather modest decline upon the arrival of a contraction which is consistent with the empirical evidence on the bank's capital levels reported during the recent crisis (see Hanson et al. (2011)). However, this decline under IFRS 9 is slightly more pronounced owning that to a stronger procyclical effect of this provisioning requirement on bank capital.[33] The impulse response of the voluntary capital buffer under the CCyB in Panel D of Figure 1 deserves an additional explanation. When the CCyB is a part of the capital regulation then the onset of a contraction mechanically increases the voluntary capital

[33]Again, this is consistent with Abad and Suarez (2018) and Krüger et al. (2018) who argue that bank capital exhibits more procyclicality under the mixed-horizon approach of IFRS 9.

buffer by releasing the reserved capital which then translates into a larger voluntary buffer.

To examine the effect of the ELM on bank stability, Figure 2 depicts the impulse response functions of the failure rates to the arrival of a contraction at $t = 0$ under the various provisioning requirements. We note an inverted U-shaped response of the failure rate to the arrival of contraction. The failure rate increases sharply from $t = 0$ reaching its peak in about 2-3 periods, and then gradually decreases converging to its unconditional mean. Consistent with our previous results, we see that apart from the scenario when the expected provisions are tax-deductible adopting the ELM helps to considerably lower the failure rate after the negative aggregate shock. Due to its larger reserves, the new US GAAP provides a better reduction in failure rate than IFRS 9.

5.4 Effect of the Arrival of a Large Loan Loss

Next, we examine the impulse response of lending and capital buffer to the arrival of a large idiosyncratic loan loss. This allows us to better understand the microprudential consequences of adopting the ELM. In particular, we study the evolution of the bank's loans and capital buffer after the bank is hit by the realization of a large loan loss rate $\tilde{\xi}$ at time $t = 0$, that is $\xi_0 = \tilde{\xi}$. For the purpose of this exercise we let $\tilde{\xi}$ correspond to the 93rd percentile of ξ_t, that is $F(\tilde{\xi}; s_t) \approx 0.93$ which implies the loan loss rate of about 4.0% in an expansion and about 9.8% in a contraction. At time $t = 0$ the bank's endogenous state is characterized by the unconditional means (i.e., the average bank). Given this initial state, we simulate 250,000 paths of the variables of interest. The bank's impulse responses to $\xi_0 = \tilde{\xi}$ are then computed as the average across these paths.[34]

Figure 3 depicts the impulse response functions of new loans N_t, outstanding loans L_t, and the voluntary capital buffer Ω_t to the arrival of $\tilde{\xi}$ at $t = 0$. Again we consider the following scenarios: when the expected provisions are tax-deductible (Panel A), when the expected provisions are not tax-deductible (Panel B), when the expected provisions are tax-deductible and the bank loss limitations is reduced by setting $\tau^{-} = 0.1$ (Panel C), and finally when the expected provisions are tax-deductible and the bank is subject to the CCyB constraint (Panel D). The impulse response functions are depicted for the ILM, IRB, IFRS 9, and the new US GAAP case. Finally, the impulse response functions for new and outstanding loans are depicted in terms of relative deviations from

[34] The aggregate state prior to and at $t = 0$ s_{-1} and s_0 are sampled from the respective unconditional distribution. Therefore, the impulse responses are averaged across aggregate state.

unconditional means, whereas for the voluntary capital buffer these are in levels.

The difference between how the bank's lending responds to the negative idiosyncratic shock under the ILM and ELM is quite different from the response to the negative aggregate shock. Figure 3 highlights a relatively smaller contraction in lending under the ELM (IFRS 9 and US-GAAP) than under the ILM/IRB upon realizing large losses. This is because the bank that follows the expected loss approach has substantially larger loan loss reserves. These larger reserves provide an additional cushion to better accommodate loan losses, thereby enabling the bank to lend more when it gets severely hit. It is important to stress, however, that this result is not specific to expected provisioning per se, but rather has to do with increased provisioning requirement. This point is reflected in Figure 3 which suggests that the on-impact contraction in new loans to a loss is decreasing with the average provisioning rate (i.e, the on-impact effect is reduced as we move from ILM to IRB then to IFRS 9, finally it is the smallest under US GAAP). The impulse response of the outstanding loans in Figure 3 does not produce an inverted hump shape since the idiosyncratic shock is iid, and thus, lacks any persistence.

The impulse responses of the voluntary capital buffer in Figure 3, unlike those in Figure 1, do not show the pronounced U-shape. Our model suggests that on-average there is little response in the voluntary capital buffer to this shock. Intuitively, the choice of the voluntary buffer is primarily determined by the future distribution of losses. Since the loss rate conditional on the aggregate state is iid its realization does not have a first-order effect on the choice of the voluntary capital buffer.

5.5 Extensions and Discussion

In this subsection, we provide an important extension of our model which allows for the delayed response of the bank's profits to the aggregate shock. We further discuss some limitations of our analysis and other potential extensions of our model.

5.5.1 Delayed Response of Profits to the Aggregate Shock

We have so far maintained an assumption that the arrival of a contraction has a contemporaneous effect on the bank's profits. Under this assumption, the ELM implies a double blow to the bank's profits as both realized and expected losses increase simultaneously upon the deterioration of the aggregate state. Such an assumption may not perfectly reflect reality since empirical evidence suggests that it is not unusual for banks to report positive profits at the start of a recession. For example, the return on average assets for US banks was positive before the start of the financial crisis in 2008.[35]

We consider alternative settings where we assume that the bank's balance sheet responds with some latency to the change in the aggregate state. In this case, the arrival of a contraction would initially only increase the bank's expected losses without affecting the realized losses. As a result, the procyclical effect of the ELM that comes from recognizing the increased expected losses should be somewhat dampened. Moreover, the delay in the response of profits allows the bank to effectively anticipate the upcoming deterioration in the profits via provisioning for expected losses. As a result, the bank's lending capacity upon being hit by the increased losses improves.[36]

Formally, we assume that there is a latency of one period between the change in the aggregate state and the bank's profits. That is, the bank's profits at time t are given by

$$\begin{aligned}\pi_t :=& \pi\left(L_t, B_t, N_t, R_{t+1}, R_t, \xi_t, s_t, s_{t-1}\right) \\ =& r^L_{s_{t-1}}(1-\hat{\xi}_t)L_t - rB_t - C(N_t) - \hat{\xi}_t\lambda_{s_{t-1}}L_t - (R_{t+1}-R_t) - \iota.\end{aligned} \tag{26}$$

where the distribution of the loss rate at time t, $\hat{\xi}_t$, now depends on the previous period aggregate state, that is

$$\hat{\xi}_t \sim F(\hat{\xi}_t; s_{t-1}).$$

This effectively implies that from the point of view of the current period, the next period repayment and losses are determined up to the aggregate state.

Since the assumption of the delayed response of the profits affects the conditional rather than unconditional expected losses, only the provisioning rates under the ELM must be modified. The

[35]For example, Lehman Brothers reported a net income of a record $4.2 billion in 2007.

[36]Some papers which examine the cyclical effect of the ELM on provisions assume that banks are able to foresee the turn in the business cycle (for example, Cohen and Edwards (2017) assumes that the bank can perfectly foresee its losses two years ahead, whereas Chae et al. (2019) allow the bank to anticipate its losses two quarters ahead). Under this assumption, the bank following the ELM would naturally provision in anticipation of the increased losses which in turn should make lending less procyclical. Abad and Suarez (2018), however, provide an extensive literature review on the (in)ability of the professional forecasters to predict contractions. The main message from this literature, somewhat unsurprisingly, is that there is little evidence that the change in the business cycle can be consistently forecast. Our assumption of the delayed response in profits to the change in the aggregate state does not rely on the forecastability of the aggregate state beyond the knowledge of its distribution, yet mechanically it shares some similarities with it.

one-year discounted expected loss for a unit loan is now given by

$$\hat{\theta}_{s_t}^{1Y} = \frac{1}{1+d_{s_t}}\mathbb{E}[\lambda_{s_t}\xi_{t+1}|s_t] = \frac{1}{1+d_{s_t}}\lambda_{s_t}p_{s_t},$$

whereas the lifetime discounted expected loss is given recursively by

$$\hat{\theta}_{s_t}^{LT} = \frac{1}{1+d_{s_t}}\left(\lambda_{s_t}p_{s_t} + (1-p_{s_t})(1-\delta)\mathbb{E}[\hat{\theta}_{s_{t+1}}^{LT}|s_t]\right).$$

Finally, we assume that the latency applies neither to the cost of external equity nor to the capital requirement.

Table 8 presents the calibrated provisioning rates under the various provisioning requirements obtained by solving the model under the benchmark parameter value of Table 1. The effect of the latency assumption on the provisioning rates can be seen by comparing Tables 2 and 8. As a result of this assumption, the provisioning rates under IFRS 9 and GAAP become even more countercyclical which can be seen by increased magnitudes of the spreads $\theta_g - \theta_b$. Whereas the effect on the unconditional rates is relatively small, the difference between the provisioning rates in good and bad times increases with the latent response to the aggregate state. Intuitively, the latency implies that the bank better anticipates the next period losses, therefore it provisions for expected losses more when times are bad and less when they are good.

Table 9 summarizes the effect of the expected loss model on the cyclicality of bank lending and stability under the assumption of latent losses.[37] The results indicate that even with the delayed response of profits, lending is still more procyclical under ELM than ILM (similar to the baseline settings in Table 4). Similarly, banks are less likely to default under ELM.

There is however a difference in how banks recover from contractions when losses are not realized immediately. To better illustrate this, we again employ the impulse response functions. Figure 4 presents the impulse response function of lending and voluntary capital buffer to the arrival of a contraction at $t = 0$. As before, we assume that prior to the contraction the bank is in an expansionary aggregate state, $s_{-1} = g$, and its endogenous state is characterized by the unconditional mean, that is $L_0 = L := \mathbb{E}[L_t]$ and $\Omega_0 = \Omega := \mathbb{E}[\Omega_t]$. There are some similarities in the

[37] Here we only report the results when expected provisions are tax-deductible. The results for other cases are consistent with the results under the baseline settings and are available on request.

impulse responses to those under the baseline setting in Figure 1. Under the ELM the bank still cuts more on new loans upon the arrival of a contraction than under the ILM. Even when profits do not immediately respond to the arrival of a contraction, the fact that the bank needs to recognize the increased expected losses coupled with the anticipation of the deterioration in the profits next period results in a sharper drop in lending.

The difference is how the bank recovers from the onset of the contraction. Already in the next period, the bank tends to originate more loans under the ELM than ILM. This is because under the latency of profits the bank recognizes the increased expected losses before and not after they realized as under the baseline settings. As a result, despite a sharper on-impact drop in new loans under the ELM, the corresponding response of outstanding loans to the arrival of a contraction exhibits about the same depth as under the ILM, albeit it unfolds more abruptly.

For completeness, Figure 5 reports the impulse response function of default rate to the arrival of a contraction at $t = 0$. Overall these responses are qualitatively similar to those under the baseline settings in Figure 2.

Overall our results suggest that even when the arrival of a contraction erodes the bank's balance sheet with a delay, thereby allowing the bank to anticipate the upcoming losses, the ELM is still more procyclical than ILM. In particular, as the bank learns about the increased upcoming losses it cuts on new loans more under the ELM than the ILM. However, the procyclicality of the ELM is now partially mitigated as the bank recognizes the bulk of expected losses before these losses realize. This allows the bank to supply more loans in the following periods after the arrival of a contraction.[38]

[38] This extension can have a different interpretation in-line with the perfect anticipation of the aggregate state similar to Cohen and Edwards (2017) and Chae et al. (2019). By redefining s_{t-1} as s_t, we could interpret this extension as the one in which the bank receives a perfect signal at time t about the next period aggregate state s_{t+1}. In that case, the bank effectively anticipates the next-period aggregate state. Under such an interpretation period $t = 0$ in Figure 4 would correspond to an expansionary aggregate state in which the bank learns about the imminent arrival of a contraction at $t = 1$. In this case, our model would suggest that the arrival of a contraction causes a smaller drop in the new loans under the ELM than under the ILM. This is because with the ability to fully anticipate the turn in the business cycle the bank is able to recognize the bulk of losses before they materialize. However, upon learning about the upcoming contraction the bank operating under the ELM would be forced to cut on new loans more than that under the ILM. This, however, raises a new potential issue with the ELM. By supplying fewer loans upon learning about the upcoming contraction, the bank operating under the ELM may effectively induce the recession to unfold earlier. After all, if one of the problems with the procyclicality of lending is that it may contribute to a credit crunch then it cutting on new loans right before the start of a contraction is hardly a solution.

5.5.2 Other Possible Extensions and Discussion

Transparency and Misreporting of Expected Losses

One aspect of the ELM which we do not consider in our analysis is the information content of expected provisions. One of the potential benefits of the ELM as argued in Financial Stability Forum Report (2009) is that it "*is consistent with financial statement users' needs for transparency regarding changes in credit trends.*" When there is asymmetric information such that the bank insiders know more about the state of the bank than other market participants, expected provisions, provided that they are properly estimated and truthfully disclosed, can be informative for the outsiders. Therefore, any potential cost of expected provisioning should be compared to the benefits it may create by increasing the transparency about the credit risk of the bank.

In a related but separate issue, we have also assumed that the bank truthfully reports expected losses. In reality, the banks are given a considerable amount of discretion in how to estimate their expected losses. Bischof, Laux, and Leuz (2019) stress that one of the main reasons behind delayed provisions during the episode of the recent financial crisis was likely the banks' reluctance to recognize (or disclose) losses and weak enforcement. Moreover, there is empirical evidence that that banks underreport their portfolio risk to reduce the pressure from the minimum capital regulation (Mariathasan and Merrouche (2014), Plosser and Santos (2014)). Hence, reporting discretion and enforcement deserve careful consideration. There is indeed merit to the argument that the banks would use their discretion to misreport their expected losses. For example, our analysis suggests that the banks would have incentives to reduce expected provisions at least during bad times (when the tax advantage of provisions matter less and the bank is more constrained by the minimum capital regulation). This reduction of the expected losses can be achieved either by reducing the default probability of loans, that is by improving lending standards, or by reporting a better quality of loans, that is by misreporting the quality of loan portfolio. In our model, the latter would, for example, correspond to underreporting a fraction of stage 2 loans. Whether with the adoption of the ELM the bank is more likely to actually improve its loan quality or simply underreport the risk instead will depend on the quality of regulatory enforcement. After all, the bank would try to minimize the cost associated with reducing the procyclical effect of the ELM. The better the quality of the regulatory audit the more likely the bank is to improve its lending standards.[39]

Although the full analysis of the incentives to misreport expected losses (and the broader impact of transparency) is beyond the scope of this paper, our model does provide some insights on which trade-off drives the incentives of discretion. On the one hand, the banks would like to report lower expected losses since this would effectively reduce the capital requirement. On the other hand, in good times, when the capital is abundant, the bank in our model would try to overstate expected losses to decrease the tax bill. However, overreporting expected losses in good times could give rise to additional costs that originate from the market reaction to such bad news. After all, reporting higher expected losses is a bad signal about the bank. Therefore, it would be hard to say a priori whether banks would indeed tend to overstate their expected losses in good times as they would have to trade off the benefits of tax shields and the cost of disclosing a bad signal about their standings.

Aggregate Risk Exposure and Loan Maturity

There are two elements that the bank cannot choose in our model but which are potentially important. First is the choice of exposure to aggregate risk, and, second, the choice of loan maturity.

The choice of exposure to aggregate risk is important because the procyclical effect of the ELM comes from the countercyclicality of loan losses. The deterioration of the aggregate state increases the expected losses which in turn raises the required provisions reducing the bank's lending capacity. The bank responds by cutting on loans. Therefore, the ELM effectively imposes a penalty on procyclical loans. As such a natural extension of our analysis is to allow the bank to control the composition of its loan portfolio with respect to aggregate risk exposure.[40]. Then by lowering the exposure of its loan portfolio to aggregate risk the bank is able to mitigate the procyclical effect of the ELM and, thus, lend more at the onset of a contraction. This could

Incorporating the choice of aggregate risk exposure into our analysis suggests that there are two opposite ways the ELM affects the choice of aggregate risk exposure.[41] First, under the ELM the bank may want to load more aggregate risk since under the ELM it holds larger reserves (as it

[39]Interestingly, however, since IFRS 9 implies a higher sensitivity of the provisioning requirement to the change in the aggregate state than the CECL of the new US GAAP, the former induces higher incentives to either improve loan quality or misreport it.

[40]For example, this can be achieved by channeling more or less credit to procyclical industries

[41]This extension of our model to the choice of aggregate risk exposure is available on request.

provisions for expected losses on top of incurred). Intuitively, having larger reserves means that the bank is better able to withstand the realized loses without having to raise costly external equity. This allows the bank to increase the exposure to aggregate risk. On the other hand, under the ELM the bank may find it optimal to reduce the exposure to aggregate risk since the procyclical effect of the ELM is stronger when the bank's loan portfolio more correlated with the business cycle. In general the second effect will dominate if the difference between provisioning in contraction and expansion, $\theta_b^{\text{ELM}} - \theta_g^{\text{ELM}}$, is sufficiently large. Therefore, our analysis would suggest that the bank's exposure to aggregate risk is likely to be higher under the provisioning requirement of the new US GAAP than the one of IFRS 9.

Our model suggests that adopting the ELM may induce the bank to optimally change the exposure of its loan portfolio to aggregate risk. It is possible that under the ELM the bank would opt for fewer procyclical loans. Although, this can be beneficial from the stability point of view as reduced exposure to aggregate risk will result in less procyclicality and a lower default probability. On the other hand, this may compromise lending by making it less profitable: loans that exhibit less procyclicality are most likely less profitable since otherwise they would have already been issued.

More importantly, however, forcing banks to lower their exposures to aggregate risk may have an impact on the type of lending they do. For example, the banks may shift their lending to less procyclical industries which may lead to inefficiencies in resource allocation. Or the banks may start to favor transaction lending relatively more than relationship lending. Consistent with Bolton, Freixas, Gambacorta, and Mistrulli (2016) relationship lending is procyclical by its nature as it is the firms that are exposed to the aggregate risk that value relationship banking more. At the same time, Bolton et al. (2016) provide some empirical evidence that relationship lending helps to dampen the effects of a credit crunch.

The choice of loan maturity is important because both IFRS 9 and the new US GAAP requires the bank to provision for lifetime expected losses. Hence, any pursuit to decrease the expected losses would incentivize banks to lower the maturity of the loans they grant. It is straightforward to show that in our model the provisioning rate for lifetime losses $\theta_{s_t}^{LT}$ is increasing in average maturity ($1/\delta$). The bank then could trade-off the decrease of maturity (which lowers the required provisions) with a decrease in loan profitability. After all, if lowering maturity was not associated with the decline of profitability the bank would have chosen such maturity in the first place.

6 Conclusion

The aftermath of the recent financial crisis brought up the discussion on the effect of provisioning rules on bank lending. The incurred loss approach has been criticized for potentially being procyclical and is being replaced with an alternative more forward-looking expected loss approach which is meant to reduce lending procyclicality. The literature on bank loan loss provisioning, however, offers little theory on how provisioning requirements affect the bank's optimal trade-offs. Our paper offers insight into the mechanism through which provisioning requirements affect bank optimal behavior.

We show that when provisions for future losses are not tax-deductible provisioning requirement for future losses functions exactly as the minimum capital requirement. This insight is useful as it informs the policy debate around macro- and micro-prudential regulation that capital requirements and accounting standards on provisioning cannot be isolated from each other. As such increasing provisioning requirement always reduces default probability, as it improves the bank's loss absorption capacity, but may either aggravate or mitigate lending procyclicality. In particular, increasing required provisions conditional on contraction (expansion) aggravates (mitigate) lending procyclicality.

Furthermore, we show that the tax treatment of provisions matters. When provisions for future losses are tax-deductible the provisioning requirement induces a tax subsidy. Due to loss limitations, this subsidy is more valuable in good times than in bad. This aggravates lending procyclicality and limits the ability of the provisioning requirement to lower default probability. However, relaxing loss limitations can help to lower this procyclical effect of the ELM.

Our quantitative analysis of the long-term implications of adopting a provisioning requirement based on expected losses suggests that it may aggravate lending procyclicality, reduce the overall supply of loans, but also lower default probability. Our model predicts that the magnitudes of these effects are economically meaningful.

Appendix

A Discounted Lifetime Losses

The discounted lifetime losses on a unit of stage i loans can be written recursively as

$$\theta_{s_t}^{LT} = \frac{1}{1+d_{s_t}} \mathbb{E}[\lambda_{s_{t+1}} \xi_{t+1} + (1-\xi_{t+1})(1-\delta)\theta_{s_{t+1}}^{LT} | s_t]. \tag{A1}$$

The above equation can be written in matrix form as

$$\bar{\theta}^{LT} = A\bar{\theta}^{LT} + \mu, \tag{A2}$$

where $\bar{\theta}_{s_t}^{LT} = \left[\theta_g^{LT}, \theta_b^{LT}\right]'$ and A is a 2×2 matrix with the coefficients given by

$$a_{11} = \frac{1}{1+d_g} q_{g,g} \left(1 - p_g^i\right)(1-\delta),$$

$$a_{12} = \frac{1}{1+d_g} (1 - q_{g,g}) \left(1 - p_b^i\right)(1-\delta),$$

$$a_{21} = \frac{1}{1+d_b} (1 - q_{b,b}) \left(1 - p_g^i\right)(1-\delta),$$

$$a_{22} = \frac{1}{1+d_b} q_{b,b} \left(1 - p_b^i\right)(1-\delta).$$

Finally, $\mu = [\mu_1, \mu_2]'$, is a 2×1 vector with

$$\mu_1 = \frac{1}{1+d_g} \left(q_{g,g}\lambda_g p_g^i + (1-q_{g,g})\lambda_b p_b^i\right),$$

$$\mu_2 = \frac{1}{1+d_b} \left((1-q_{b,b})\lambda_g p_g^i + q_{b,b}\lambda_b p_b^i\right).$$

Thus,

$$\bar{\theta}^{LT} = \left(I_{2\times 2} - A\right)^{-1} \mu,$$

where $I_{2\times 2}$ is a 2×2 identity matrix.

B Numerical Solution Method

Model. The fully non-linear solution to the model (i.e., the system of equations (11)) is obtained numerically using the value function iteration method. The model has two endogenous state variables Ω_t and L_t. The grid for L_t consists of 46 points: the first point is 0 and the rest 45 points are equidistantly spaced between 0.15 and 1.25. The grid for Ω_t consists of 30 equidistantly spaced points between 0 and 0.05. We use a linear interpolation method for the grid of choice variables Ω_{t+1} and L_{t+1} (implemented by applying the *interp1* Matlab function to the original grids of Ω_t and L_t with the query point equal to 0.08). As a result of linear interpolation, the grids for Ω_{t+1} and L_{t+1} consist of 363 and 563 points, respectively. The high density of the grid for the choice variables is highly important in order to obtain a reliable approximation of the solution to our model. This is because the loss rate ξ_t and, thus the provisioning rate θ_{s_t}, have relatively small magnitudes. Therefore, in order to pick up any effect from a relatively small change in θ_{s_t} (say the difference between IFRS 9 and US GAAP) it is crucial that the grids for Ω_{t+1} and L_{t+1} are dense enough.

For the numerical representation of the exogenous state the random variable ξ_t is discretized. The grid of the ξ_t^i's support consists of 12 points (in each aggregate state). Repullo and Suarez (2012) show that under the single common risk factor model of Vasicek (2002) the default rate (for i type loan) can be written as

$$\xi_t^i = g(u; s_t) = \Phi\left(\frac{\Phi^{-1}(p_{s_t}^i) - \sqrt{\rho_{s_t}^i}\,u}{\sqrt{1-\rho_{s_t}^i}}\right),$$

where $\Phi(.)$ is the standard normal $p_{s_t}^i$ and $\rho_{s_t}^i$ are defined in the text, and $u \sim \mathcal{N}(0,1)$. Therefore the discrete approximation of ξ_t^i is obtained by discretizing u which is performed using Tauchen (1986) approach (with multiple $m = 2$). Because we have 2 possible realizations of aggregate states and also record the one-period history of the aggregate state (s_{t-1}) the space of exogenous state consists of $2 \times 2 \times 12 = 48$ points.

To compute the moments implied by the model, we simulate our model for 40,000 periods. The first 200 observations are dropped when computing the moments in order to avoid the initial value having any effect. When the bank default on the simulation path it is replaced starting from the next period with a new bank with of the average size (i.e., with L_t and Ω_t given by unconditional means). Given that default is a rare event the replacement rule does not have any profound effect on the moments.

Generalized Impulse Response Functions. The generalized impulse response of the variable of interest Y_t is the difference between the conditional on a shock expectation of Y_t and the unconditional expectation of Y_t. Suppose we are interested in the average impulse response of variable Y_t (which can be L_t, N_t, or Ω_t, for example) to a shock in the exogenous variable (either s_t or ξ_t). Then we first specify the initial starting values such that they are representative of the average endogenous state ($L_0 = \mathbb{E}[L_t]$ and $\Omega_0 = \mathbb{E}[\Omega_t]$) and that the exogenous state correspond to the shock scenario which we want to examine (for example, if we want to study the effect of the change in the aggregate state from expansion to contraction then we set $s_{-1} = g$, $s_0 = b$, and $\xi_0 = \mathbb{E}[\xi_t|s_t = b]$). Let the state vector which reflects this initial conditions be given by Θ_0. Then the generalized impulse response of Y_t to Θ_0 at time $j \in [0, T]$ is given by

$$\mathbb{E}[Y_j|\Theta_0] - \mathbb{E}[Y_t].$$

The first term above, the conditional expectation is computed in the following way. We simulate the N paths of length T of Y_t with the starting value Θ_0. The resulted of this simulations is a $N \times T$ matrix. Taking the mean (column-wise) of this matrix then produces the numerical approximation of $\mathbb{E}[Y_j|\Theta_0]$. In our simulation exercise, we set $N = 250,000$ and $T = 20$ (but report only $T = 9$). The second term - the unconditional expectation - is computed by evaluating unconditional mean Y_t based on simulating the model for 40,000 periods.

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Table 1

Model Parameters.

Parameter	Description	Contraction	Expansion
q_{s_t,s_t}	Transition probability of remaining in the state	0.5	0.852
$p^1_{s_t}$	Default probability of stage 1 loan	1.90%	0.54%
$p^2_{s_t}$	Default probability of stage 2 loan	11.50%	6.05%
ω_{s_t}	Fraction of stage 1 loans	0.81	0.85
$1/\delta$	Average maturity of loans	5 (years)	5 (years)
λ_{s_t}	Loss given default rate	0.40	0.30
$r^L_{s_t}$	Interest rate on loan portfolio	4.89%	5.34%
r	Risk-free rate	1.80%	1.80%
β	Discount rate	0.98	0.98
ϕ	Loan adjustment cost parameter	0.50	0.50
ψ	Fire-sale discount	1.50	1.50
ι	Fixed cost of running the bank	0.0148	0.0148
$\eta^0_{s_t}$	Fixed cost of issuing external equity	0.01	0.0001
$\eta^1_{s_t}$	Variable cost of issuing external equity	0.24	0.05
τ^+	Corporate tax rate	0.20	0.20
τ^-	Corporate tax rebate rate	{0,0.1}	{0,0.1}
$\rho^1_{s_t}$	Loan default correlation stage 1 loans	0.166	0.212
$\rho^2_{s_t}$	Loan default correlation stage 2 loans	0.120	0.126
ν_1	Minimum capital requirement for stage 1 loans	0.085	0.085
ν_2	Minimum capital requirement for stage 2 loans	0.144	0.144
κ_{s_t}	Total minimum capital requirement	0.097	0.094

Table 2

Provisioning Rates under Different Provisioning Rules. This table presents provisioning rates θ_{s_t} (%) for various provisioning requirements conditional on aggregate state ($s_t = g$ is an expansion and $s_t = b$ is a contraction). For the Incurred Loss Model (ILM) provisioning rate is zero as it is assumed that the bank charges off bad loans during the same period it provisions for their related incurred losses. Provisioning rates are reported for the Internal Risk-Based (IRB) approach, IFRS 9, and US GAAP.

		ILM	IRB	IFRS 9	GAAP
Category 1 in expansion	θ_g^1	0.00%	0.34%	0.24%	1.26%
Category 2 in expansion	θ_g^2	0.00%	2.92%	7.61%	8.59%
Category 1 in contraction	θ_b^1	0.00%	0.34%	0.44%	1.54%
Category 2 in contraction	θ_b^2	0.00%	2.92%	8.73%	9.69%
Total in expansion	θ_g	0.00%	0.73%	1.34%	2.36%
Total in contraction	θ_b	0.00%	0.84%	2.04%	3.12%
Difference across aggregate state	$\theta_g - \theta_b$	0.00%	-0.11%	-0.70%	-0.75%
Total unconditional mean	$\mathbb{E}[\theta_{s_t}]$	0.00%	0.81%	1.88%	2.94%

Table 3

Data and Model Moments under Benchmark Calibration. This table presents the moments implied by the model and real data. The moments implied by the model are computed under the ILM case (those under the IRB are similar). The moments are computed based on the data from simulating the model for 40,000 periods and excluding the first 200 observations. The real-world data moments are representative of large US banks. The mean and standard charge-off rate is reported in the Economic Research and Data section of the Board of Governors of the Federal Reserve System website (Charge-Off Rates All Banks, SA 1992-2019). *Note: since in our model the bank does not accumulate NPLs the charge-off rate and loss rate are the same objects.* The mean payout ratio is reported in Floyd et al. (2015). The data on average CET1 ratio of the US banks is not readily available, we, therefore, report the average total T1 ratio for US banks (FRED "BOGZ1FL010000016Q" average across 2011-2019). The standard deviation of loan growth rate is computed using the data from Federal Reserve Economic Data, St. Louis Fed (time series "CILACBQ158SBOG"). The failure rate is the annualized rate of the quarterly estimates from Mankart et al. (forthcoming). The probability of issuing equity in a given year for a US bank is estimated in Dinger and Vallascas (2016). The rest of the moments are from Cziraki et al. (2017).

Moment	Model	Data
Mean Charge-off Rate	0.66%	0.86%
St.d. Charge-off Rate	0.49%	0.60%
Mean CET1 Ratio	10.5%	12.95%
St.d. Loan Growth Rate	7.50%	8.04%
Failure Probability	0.47%	0.32%
Probability of Issuing Equity	2.72%	5.08%
Mean Payout Ratio	45.6%	35-50%
Mean Dividends/Equity	3.04%	4.54%

Table 4

The Effect of Adopting the Expected Loss Model. This table presents unconditional and conditional (on the aggregate state) first moments of various endogenous variables implied by the model under different provisioning rules. The model is solved and simulated under the Incurred Loss Model (ILM), the provisioning requirement implied by the Internal Ratings-Based (IRB) approach, the expected loss model of IFRS 9, and the expected loss model of the new US GAAP. The statistics are constructed based on simulating the model for 40000 periods (with the first 200 observations excluded). Δ_j^i denotes the relative difference in the variable of interest between rule i and j either in terms of percentage or percentage point (pp).

Variable	Aggregate State	ILM	IRB	IFRS9	GAAP	Δ_{ILM}^{IFRS9}	Δ_{ILM}^{GAAP}	Δ_{IRB}^{IFRS9}	Δ_{IRB}^{GAAP}
	Unconditional	0.2224	0.2220	0.2208	0.2207	-0.75%	-0.78%	-0.57%	-0.60%
New Loans, N_t	Contraction	0.1843	0.1829	0.1709	0.1706	-7.55%	-7.77%	-6.78%	-7.00%
	Expansion	0.2336	0.2334	0.2353	0.2354	0.75%	0.77%	0.80%	0.81%
	Unconditional	1.0359	1.0340	1.0282	1.0280	-0.75%	-0.78%	-0.57%	-0.60%
Outstanding Loans, L_{t+1}	Contraction	0.9620	0.9589	0.9392	0.9382	-2.39%	-2.51%	-2.08%	-2.19%
	Expansion	1.0574	1.0559	1.0541	1.0542	-0.31%	-0.31%	-0.17%	-0.17%
	Unconditional	3.07%	2.55%	2.33%	1.73%	-0.74pp	-1.34pp	-0.23pp	-0.82pp
Voluntary buffer, Ω_{t+1}	Contraction	2.90%	2.43%	1.89%	1.48%	-1.01pp	-1.42pp	-0.55pp	-0.95pp
	Expansion	3.12%	2.58%	2.45%	1.80%	-0.67pp	-1.32pp	-0.13pp	-0.78pp
	Unconditional	10.53%	10.10%	9.91%	9.42%	-0.63pp	-1.12pp	-0.19pp	-0.68pp
CET1_{t+1}	Contraction	10.19%	9.82%	9.36%	9.08%	-0.83pp	-1.11pp	-0.46pp	-0.74pp
	Expansion	10.63%	10.18%	10.07%	9.52%	-0.57pp	-1.12pp	-0.11pp	-0.66pp
	Unconditional	0.00%	0.00%	0.00%	0.00%	0.00pp	0.00pp	0.00pp	0.00pp
Loan growth, $ln(L_{t+1}/L_t)$	Contraction	-5.02%	-5.08%	-6.32%	-6.12%	-1.30pp	-1.10pp	-1.24pp	-1.04pp
	Expansion	1.46%	1.48%	1.84%	1.79%	0.38pp	0.32pp	0.36pp	0.30pp
	Unconditional	0.47%	0.44%	0.46%	0.35%	-0.01pp	-0.12pp	0.02pp	-0.09pp
Failure rate	Contraction	1.69%	1.55%	1.65%	1.20%	-0.04pp	-0.49pp	0.10pp	-0.34pp
	Expansion	0.11%	0.12%	0.12%	0.10%	0.00pp	-0.01pp	0.00pp	-0.02pp
	Unconditional	2.72%	3.15%	2.73%	2.74%	0.01pp	0.02pp	-0.42pp	-0.41pp
Equity issuance probability	Contraction	0.43%	1.52%	0.38%	0.28%	-0.06pp	-0.16pp	-1.15pp	-1.25pp
	Expansion	3.41%	3.64%	3.43%	3.47%	0.03pp	0.06pp	-0.20pp	-0.17pp

Table 5

The Effect of Adopting the Expected Loss Model when Expected Provisions Are Not Tax-Deductible. This table presents unconditional and conditional (on the aggregate state) first moments of various endogenous variables implied by the model under different provisioning requirement. The expected provisions are not tax-deductible, that is $\tau(\pi_t)\Delta R_{t+1}$ is subtracted from the after-tax profits.The model is solved and simulated under the Incurred Loss Model (ILM), the provisioning requirement implied by the Internal Ratings-Based (IRB) approach, the expected loss model of IFRS 9, and the expected loss model of the new US GAAP. The statistics are constructed based on simulating the model for 40000 periods (with the first 200 observations excluded). $\Delta^{\mathrm{i}}_{\mathrm{j}}$ denotes the relative difference in the variable of interest between rule i and j either in terms of percentage or percentage point (pp).

Variable	Aggregate State	ILM	IRB	IFRS9	GAAP	Δ^{IFRS9}_{ILM}	Δ^{GAAP}_{ILM}	Δ^{IFRS9}_{IRB}	Δ^{GAAP}_{IRB}
New Loans, N_t	Unconditional	0.2224	0.2220	0.2215	0.2209	-0.43%	-0.69%	-0.25%	-0.51%
	Contraction	0.1843	0.1829	0.1734	0.1732	-6.11%	-6.21%	-5.34%	-5.44%
	Expansion	0.2336	0.2334	0.2355	0.2348	0.83%	0.53%	0.88%	0.58%
Outstanding Loans, L_{t+1}	Unconditional	1.0359	1.0340	1.0315	1.0288	-0.42%	-0.69%	-0.24%	-0.51%
	Contraction	0.9620	0.9589	0.9446	0.9426	-1.83%	-2.04%	-1.51%	-1.72%
	Expansion	1.0574	1.0559	1.0569	1.0539	-0.05%	-0.33%	0.09%	-0.19%
Voluntary buffer, Ω_{t+1}	Unconditional	3.07%	2.55%	2.38%	1.85%	-0.69pp	-1.22pp	-0.17pp	-0.70pp
	Contraction	2.90%	2.43%	1.82%	1.50%	-1.08pp	-1.39pp	-0.61pp	-0.93pp
	Expansion	3.12%	2.58%	2.54%	1.95%	-0.58pp	-1.17pp	-0.04pp	-0.63pp
$\mathrm{CET1}_{t+1}$	Unconditional	10.53%	10.10%	9.97%	9.53%	-0.56pp	-1.00pp	-0.13pp	-0.57pp
	Contraction	10.19%	9.82%	9.37%	9.13%	-0.82pp	-1.06pp	-0.45pp	-0.69pp
	Expansion	10.63%	10.18%	10.15%	9.65%	-0.49pp	-0.99pp	-0.03pp	-0.53pp
Loan growth, $ln(L_{t+1}/L_t)$	Unconditional	0.00%	0.00%	0.00%	0.00%	0.00pp	0.00pp	0.00pp	0.00pp
	Contraction	-5.02%	-5.08%	-5.92%	-5.87%	-0.91pp	-0.85pp	-0.84pp	-0.79pp
	Expansion	1.46%	1.48%	1.73%	1.71%	0.26pp	0.25pp	0.25pp	0.23pp
Failure rate	Unconditional	0.47%	0.44%	0.31%	0.26%	-0.16pp	-0.21pp	-0.13pp	-0.18pp
	Contraction	1.69%	1.55%	1.10%	0.90%	-0.59pp	-0.79pp	-0.44pp	-0.65pp
	Expansion	0.11%	0.12%	0.08%	0.07%	-0.04pp	-0.04pp	-0.04pp	-0.04pp
Equity issuance probability	Unconditional	2.72%	3.15%	3.63%	4.56%	0.91pp	1.84pp	0.49pp	1.41pp
	Contraction	0.43%	1.52%	1.88%	2.12%	1.45pp	1.69pp	0.36pp	0.60pp
	Expansion	3.41%	3.64%	4.17%	5.30%	0.76pp	1.89pp	0.53pp	1.66pp

Table 6

The Effect of Adopting the Expected Loss Model with Relaxed Loss Limitations. This table presents unconditional and conditional (on the aggregate state) first moments of various endogenous variables implied by the model under different provisioning requirements. The bank's loss limitations are improved by setting $\tau^- = 0.1$. The model is solved and simulated under the Incurred Loss Model (ILM), the provisioning requirement implied by the Internal Ratings-Based (IRB) approach, the expected loss model of IFRS 9, and the expected loss model of the new US GAAP. The statistics are constructed based on simulating the model for 40000 periods (with the first 200 observations excluded). Δ_j^i denotes the relative difference in the variable of interest between rule i and j either in terms of percentage or percentage point (pp).

Variable	Aggregate State	ILM	IRB	IFRS9	GAAP	Δ_{ILM}^{IFRS9}	Δ_{ILM}^{GAAP}	Δ_{IRB}^{IFRS9}	Δ_{IRB}^{GAAP}
	Unconditional	0.2227	0.2220	0.2206	0.2206	-0.93%	-0.91%	-0.65%	-0.64%
New Loans, N_t	Contraction	0.1894	0.1875	0.1800	0.1785	-5.12%	-5.93%	-4.09%	-4.91%
	Expansion	0.2324	0.2321	0.2325	0.2329	0.04%	0.25%	0.14%	0.34%
	Unconditional	1.0368	1.0340	1.0273	1.0275	-0.93%	-0.91%	-0.65%	-0.64%
Outstanding Loans, L_{t+1}	Contraction	0.9696	0.9657	0.9503	0.9484	-2.01%	-2.20%	-1.61%	-1.80%
	Expansion	1.0564	1.0539	1.0498	1.0506	-0.63%	-0.56%	-0.39%	-0.32%
	Unconditional	2.30%	1.81%	1.91%	1.48%	-0.39pp	-0.82pp	0.10pp	-0.33pp
Voluntary buffer, Ω_{t+1}	Contraction	2.00%	1.54%	1.21%	0.99%	-0.80pp	-1.01pp	-0.33pp	-0.55pp
	Expansion	2.39%	1.89%	2.12%	1.63%	-0.27pp	-0.76pp	0.23pp	-0.27pp
	Unconditional	9.90%	9.50%	9.59%	9.23%	-0.31pp	-0.67pp	0.09pp	-0.27pp
$CET1_{t+1}$	Contraction	9.51%	9.15%	8.89%	8.74%	-0.61pp	-0.76pp	-0.26pp	-0.41pp
	Expansion	10.02%	9.60%	9.80%	9.37%	-0.23pp	-0.65pp	0.20pp	-0.22pp
	Unconditional	0.00%	0.00%	0.00%	0.00%	0.00pp	0.00pp	0.00pp	0.00pp
Loan growth, $ln(L_{t+1}/L_t)$	Contraction	-4.44%	-4.72%	-5.20%	-5.44%	-0.76pp	-1.00pp	-0.48pp	-0.72pp
	Expansion	1.30%	1.38%	1.52%	1.59%	0.22pp	0.29pp	0.14pp	0.21pp
	Unconditional	0.32%	0.28%	0.22%	0.18%	-0.09pp	-0.13pp	-0.05pp	-0.09pp
Failure rate	Contraction	1.22%	0.97%	0.87%	0.62%	-0.36pp	-0.60pp	-0.10pp	-0.34pp
	Expansion	0.05%	0.07%	0.04%	0.06%	-0.02pp	0.00pp	-0.04pp	-0.02pp
	Unconditional	2.82%	2.87%	2.85%	2.76%	0.03pp	-0.06pp	-0.02pp	-0.12pp
Equity issuance probability	Contraction	0.14%	0.20%	0.22%	0.20%	0.08pp	0.06pp	0.02pp	0.00pp
	Expansion	3.62%	3.67%	3.64%	3.52%	0.02pp	-0.10pp	-0.03pp	-0.15pp

Table 7

The Effect of Adopting the Expected Loss Model together with the Countercyclical Capital Buffer. This table presents unconditional and conditional (on the aggregate state) first moments of various endogenous variables implied by the model under different provisioning rules and when the bank is required to hold the Countercyclical Capital Buffer (CCyB). The model is solved and simulated under the Incurred Loss Model (ILM), the provisioning requirement implied by the Internal Ratings-Based (IRB) approach, the expected loss model of IFRS 9, and the expected loss model of the new US GAAP. The moments are computed based on simulating the model for 40,000 periods (with the first 200 observations excluded). $\Delta^{\mathrm{i}}_{\mathrm{j}}$ denotes the relative (percentage (%) or percentage point (pp)) difference in the variable of interest between rule i and j (where j corresponds to the respective mean under the ILM or IRB from Table 4 when the expected provisions are tax-deductible but the bank holds no CCyB.

Variable	Aggregate State	ILM +CCyB	IRB + CCyB	IFRS9 + CCyB	GAAP +CCyB	$\Delta_{ILM}^{ILM+CCyB}$	$\Delta_{IRB}^{IRB+CCyB}$	$\Delta_{ILM}^{IFRS9+CCyB}$	$\Delta_{ILM}^{GAAP+CCyB}$	$\Delta_{IRB}^{IFRS9+CCyB}$	$\Delta_{IRB}^{GAAP+CCyB}$
New Loans, N_t	Unconditional	0.2219	0.2208	0.2194	0.2190	-0.23%	-0.56%	-1.39%	-1.57%	-1.21%	-1.39%
	Contraction	0.1846	0.1841	0.1724	0.1740	0.12%	0.65%	-6.70%	-5.75%	-5.93%	-4.98%
	Expansion	0.2328	0.2315	0.2331	0.2321	-0.31%	-0.84%	-0.21%	-0.63%	-0.16%	-0.58%
Outstanding Loans, L_{t+1}	Unconditional	1.0334	1.0282	1.0216	1.0198	-0.23%	-0.56%	-1.39%	-1.57%	-1.21%	-1.39%
	Contraction	0.9608	0.9570	0.9365	0.9374	-0.12%	-0.21%	-2.68%	-2.59%	-2.36%	-2.27%
	Expansion	1.0546	1.0490	1.0464	1.0439	-0.26%	-0.66%	-1.04%	-1.29%	-0.90%	-1.15%
Voluntary buffer, Ω_{t+1}	Unconditional	0.93%	0.75%	0.61%	0.60pp	-2.14pp	-1.80pp	-2.46pp	-2.47pp	-1.94pp	-1.95pp
	Contraction	3.01%	2.85%	2.35%	2.45%	0.11pp	0.41pp	-0.55pp	-0.45pp	-0.09pp	0.01pp
	Expansion	0.32%	0.14%	0.10%	0.06%	-2.80pp	-2.44pp	-3.02pp	-3.06pp	-2.48pp	-2.52pp
CET1_{t+1}	Unconditional	10.65%	10.52%	10.40%	10.41%	0.12pp	0.42pp	-0.13pp	-0.12pp	0.30pp	0.31pp
	Contraction	10.30%	10.21%	9.80%	9.94%	0.11pp	0.39pp	-0.39pp	-0.25pp	-0.03pp	0.12pp
	Expansion	10.76%	10.61%	10.58%	10.55%	0.12pp	0.43pp	-0.06pp	-0.09pp	0.40pp	0.37pp
Loan growth, $ln(L_{t+1}/L_t)$	Unconditional	0.00%	0.00%	0.00%	0.00%	0.00pp	0.00pp	0.00pp	0.00pp	0.00pp	0.00pp
	Contraction	-4.95%	-4.85%	-5.78%	-5.56%	0.07pp	0.23pp	-0.76pp	-0.55pp	-0.69pp	-0.48pp
	Expansion	1.44%	1.42%	1.69%	1.62%	-0.02pp	-0.07pp	0.22pp	0.16pp	0.20pp	0.14pp
Failure rate	Unconditional	0.41%	0.31%	0.32%	0.18%	-0.06pp	-0.13pp	-0.15pp	-0.29pp	-0.12pp	-0.26pp
	Contraction	1.54%	1.19%	1.17%	0.67%	-0.16pp	-0.36pp	-0.52pp	-1.02pp	-0.38pp	-0.88pp
	Expansion	0.09%	0.06%	0.08%	0.04%	-0.03pp	-0.06pp	-0.04pp	-0.07pp	-0.04pp	-0.08pp
Equity issuance probability	Unconditional	3.31%	3.87%	3.63%	3.61%	0.59pp	0.73pp	0.91pp	0.89pp	0.48pp	0.47pp
	Contraction	0.29%	0.77%	0.22%	0.12%	-0.14pp	-0.76pp	-0.21pp	-0.31pp	-1.30pp	-1.40pp
	Expansion	4.21%	4.80%	4.64%	4.65%	0.80pp	1.16pp	1.24pp	1.24pp	1.01pp	1.01pp

Table 8

Provisioning Rates under Different Provisioning Rules under the Delayed Response of Profits. This table presents provisioning rates θ_{s_t} (%) for various provisioning requirements conditional on aggregate state ($s_t = g$ is expansion and $s_t = b$ is contraction) when there is a one-year latency between the change in the aggregate state and the bank's profits. For the Incurred Loss Model (ILM) provisioning rate is zero as it is assumed that the bank charges off bad loans during the same period it provisions for their related incurred losses. Provisioning rates are further reported for the Internal Risk-Based (IRB) approach, IFRS 9 and US GAAP.

		ILM	IRB	IFRS 9	GAAP
Category 1 in expansion	θ_g^1	0.00%	0.34%	0.15%	1.15%
Category 2 in expansion	θ_g^2	0.00%	2.92%	7.16%	8.12%
Category 1 in contraction	θ_b^1	0.00%	0.34%	0.72%	1.93%
Category 2 in contraction	θ_b^2	0.00%	2.92%	10.27%	11.26%
Total in expansion	θ_g	0.00%	0.73%	1.20%	2.19%
Total in contraction	θ_b	0.00%	0.84%	2.57%	3.74%
Difference across aggregate state	$\theta_g - \theta_b$	0.00%	-0.11%	-1.37%	-1.54%
Total unconditional mean	$\mathbb{E}[\theta_{s_t}]$	0.00%	0.81%	2.26%	3.38%

Table 9

The Effect of Adopting the Expected Loss Model under the Delayed Response of Profits. This table presents unconditional and conditional (on the aggregate state) first moments of various endogenous variables implied by the model under different provisioning rules under the assumption that bank's losses are one-period latent. The model is solved and simulated under the Incurred Loss Model (ILM), the provisioning requirement implied by the Internal Ratings-Based (IRB) approach, the expected loss model of IFRS 9, and the expected loss model of the new US GAAP. The statistics are constructed based on simulating the model for 40000 periods (with the first 200 observations excluded). Δ_j^i denotes the relative difference in the variable of interest between rule i and j either in terms of percentage or percentage point (pp).

Variable	Aggregate State	ILM	IRB	IFRS9	GAAP	Δ_{ILM}^{IFRS9}	Δ_{IRB}^{IFRS9}	Δ_{ILM}^{GAAP}	Δ_{IRB}^{GAAP}
	Unconditional	0.2234	0.2228	0.2233	0.2224	-0.02%	-0.42%	0.22%	-0.18%
New Loans, N_t	Contraction	0.1789	0.1782	0.1677	0.1653	-6.50%	-7.90%	-6.07%	-7.48%
	Expansion	0.2363	0.2359	0.2396	0.2391	1.36%	1.16%	1.56%	1.36%
	Unconditional	1.0410	1.0385	1.0411	1.0370	0.01%	-0.39%	0.25%	-0.15%
Outstanding Loans, L_{t+1}	Contraction	0.9728	0.9695	0.9569	0.9507	-1.65%	-2.29%	-1.30%	-1.95%
	Expansion	1.0609	1.0587	1.0657	1.0621	0.45%	0.11%	0.66%	0.33%
	Unconditional	1.26%	0.82%	0.43%	0.31%	-0.83pp	-0.94pp	-0.39pp	-0.51pp
Voluntary buffer, Ω_{t+1}	Contraction	2.20%	1.80%	0.79%	0.65%	-1.41pp	-1.55pp	-1.01pp	-1.15pp
	Expansion	0.98%	0.54%	0.32%	0.21%	-0.66pp	-0.77pp	-0.21pp	-0.32pp
	Unconditional	8.99%	8.63%	8.33%	8.24%	-0.67pp	-0.75pp	-0.31pp	-0.39pp
$CET1_{t+1}$	Contraction	9.73%	9.41%	8.66%	8.58%	-1.07pp	-1.15pp	-0.75pp	-0.84pp
	Expansion	8.78%	8.41%	8.23%	8.14%	-0.55pp	-0.64pp	-0.18pp	-0.26pp
	Unconditional	0.00%	0.00%	0.00%	0.00%	0.00pp	0.00pp	0.00pp	0.00pp
Loan growth, $ln(L_{t+1}/L_t)$	Contraction	-4.76%	-4.66%	-5.59%	-5.81%	-0.83pp	-1.04pp	-0.94pp	-1.15pp
	Expansion	1.39%	1.36%	1.63%	1.69%	0.24pp	0.30pp	0.27pp	0.34pp
	Unconditional	0.52%	0.48%	0.28%	0.18%	-0.25pp	-0.35pp	-0.20pp	-0.30pp
Failure rate	Contraction	1.82%	1.65%	0.91%	0.61%	-0.91pp	-1.21pp	-0.73pp	-1.03pp
	Expansion	0.14%	0.14%	0.09%	0.05%	-0.05pp	-0.09pp	-0.05pp	-0.09pp
	Unconditional	2.81%	3.57%	3.33%	3.45%	0.53pp	0.65pp	-0.24pp	-0.12pp
Equity issuance probability	Contraction	0.32%	0.90%	0.16%	0.12%	-0.17pp	-0.20pp	-0.75pp	-0.78pp
	Expansion	3.55%	4.37%	4.28%	4.44%	0.73pp	0.90pp	-0.09pp	0.07pp

Figure 1. Effect of the Arrival of a Contraction on Loans and Capital.
This figure reports the generalized impulse response function of new loans N_t, outstanding loans L_t, and voluntary capital buffer Ω_t to the arrival of a contraction at $t = 0$, that is $s_0 = b$. Prior to the contraction the bank is in an expansionary aggregate state, $s_{-1} = g$, and its endogenous state is characterized by the unconditional mean, that is $L_0 = L := \mathbb{E}[L_t]$ and $\Omega_0 = \Omega := \mathbb{E}[\Omega_t]$. The impulse response functions are expressed in terms of relative deviation from the unconditional mean for new and outstanding loans (where $N := \mathbb{E}[N_t]$) and in levels for the voluntary capital buffer. We consider four scenarios: Panel A depicts the benchmark case in which the expected provisions under the ELM are tax-deductible and $\tau^- = 0$; Panel B depicts the case when the expected provisions are not tax-deductible under the ELM; Panel C assumed the tax-deductibility of expected provisions and relaxes loss limitations by setting $\tau^- = 0.10$; finally, in Panel D the expected provisions are tax-deductible and the bank must hold the Countercyclical Capital Buffer (CCyB). Each subfigure depicts four impulse response functions corresponding to the scenario when the bank operates under the Incurred Loss Model (ILM), the Internal Ratings-Based approach (IRB), the Expected Loss Model under IFRS 9 and the new US GAAP. The impulse response function The impulse response functions are obtained by averaging 250,000 simulated paths.

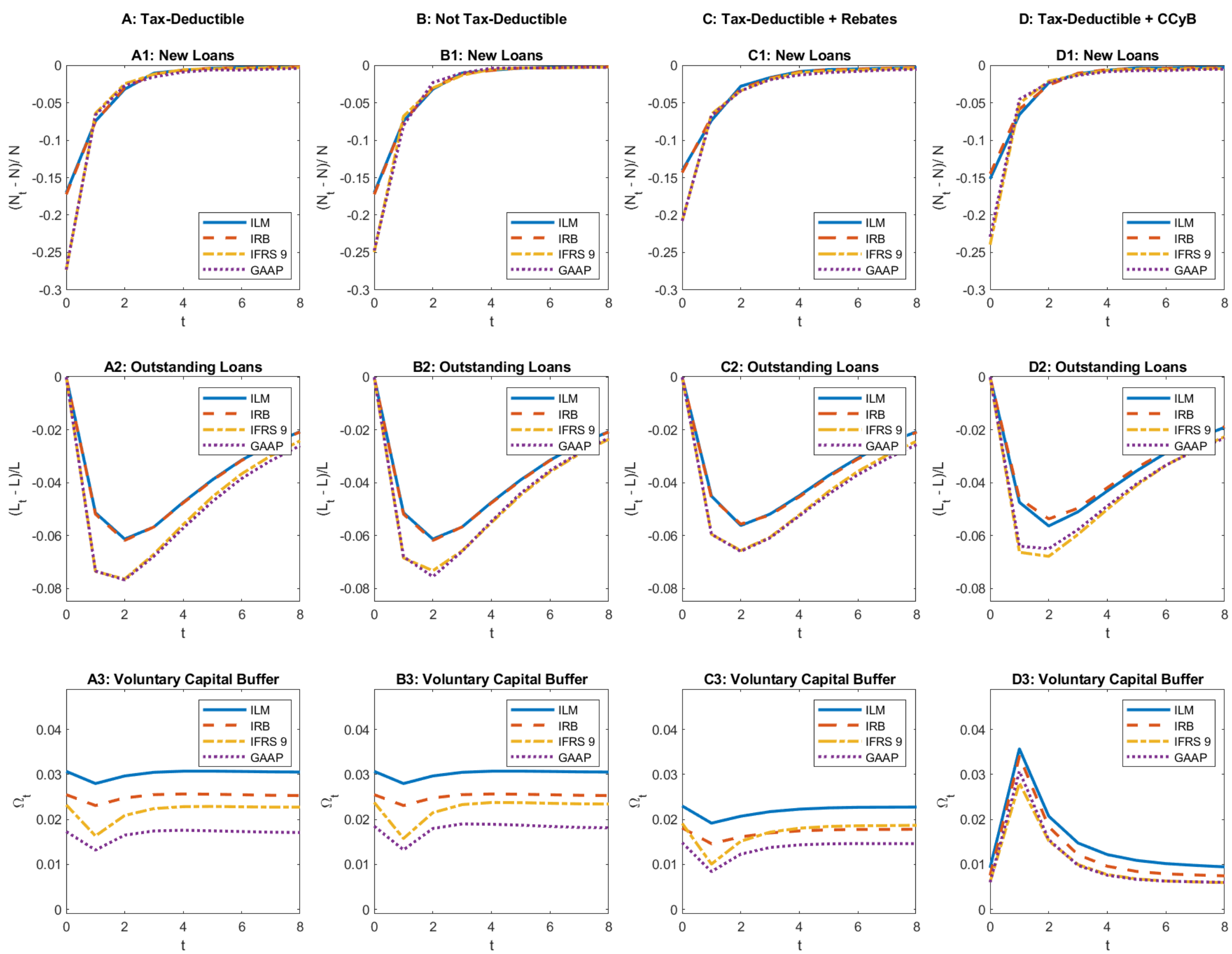

Figure 2. Effect of the Arrival of a Contraction on Default Probability.
This figure reports the generalized impulse response function of default rate to the arrival of a contraction at $t = 0$, that is $s_0 = b$. Prior to the contraction the bank is in an expansionary aggregate state, $s_{-1} = g$, and its endogenous state is characterized by the unconditional mean, that is $L_0 = L := \mathbb{E}[L_t]$ and $\Omega_0 = \Omega := \mathbb{E}[\Omega_t]$. We consider four scenarios: Panel A depicts the benchmark case in which the expected provisions under the ELM are tax-deductible and $\tau^- = 0$; Panel B depicts the case when the expected provisions are not tax-deductible under the ELM; Panel C assumed the tax-deductibility of expected provisions and relaxes loss limitations by setting $\tau^- = 0.10$; finally, in Panel D the expected provisions are tax-deductible and the bank must hold the Countercyclical Capital Buffer (CCyB). Each subfigure depicts four impulse response functions corresponding to the scenario when the bank operates under the Incurred Loss Model (ILM), the Internal Ratings-Based approach (IRB), the Expected Loss Model under IFRS 9 and the new US GAAP. The impulse response functions are obtained by averaging 250,000 simulated paths.

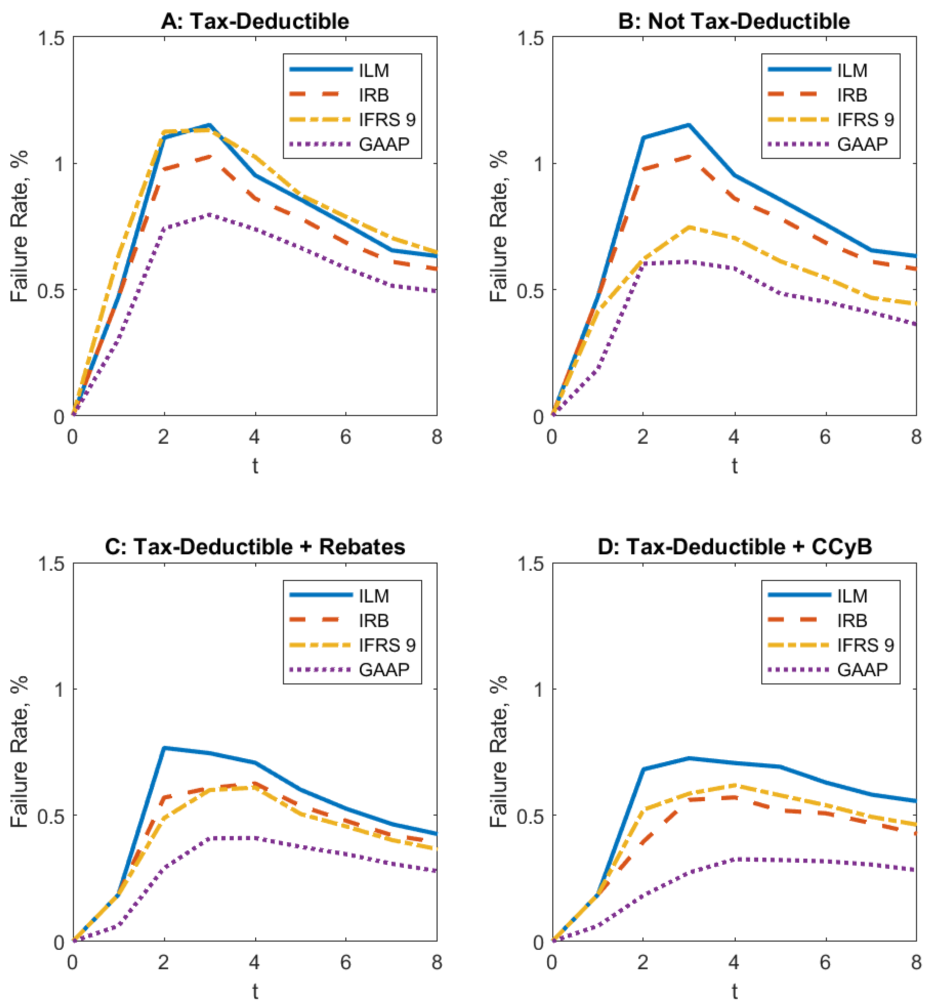

Figure 3. Effect of a Large Loan Loss on Loans and Capital.
This figure reports the generalized impulse response function of new loans N_t, outstanding loans L_t, and voluntary capital buffer Ω_t to a realization of a large loan loss rate $\tilde{\xi}$ at time t=0. $\tilde{\xi}$ is determined by $F(\tilde{\xi}; s_t) \approx 0.93$ which implies the value of about 0.098 in a contraction and 0.040 in an expansion. The impulse response functions represent the reaction of an average bank and are unconditional on the aggregate state. The impulse response functions are expressed in terms of relative deviation from the unconditional mean for new and outstanding loans (where $N := \mathbb{E}[N_t]$) and in levels for the voluntary capital buffer. We consider four scenarios: Panel A depicts the benchmark case in which the expected provisions under the ELM are tax-deductible and $\tau^- = 0$; Panel B depicts the case when the expected provisions are not tax-deductible under the ELM; Panel C assumed the tax-deductibility of expected provisions and relaxes loss limitations by setting $\tau^- = 0.10$; finally, in Panel D the expected provisions are tax-deductible and the bank must hold the Countercyclical Capital Buffer (CCyB). Each subfigure depicts four impulse response functions corresponding to the scenario when the bank operates under the Incurred Loss Model (ILM), the Internal Ratings-Based approach (IRB), the Expected Loss Model under IFRS 9 and the new US GAAP. The impulse response function The impulse response functions are obtained by averaging 250,000 simulated paths.

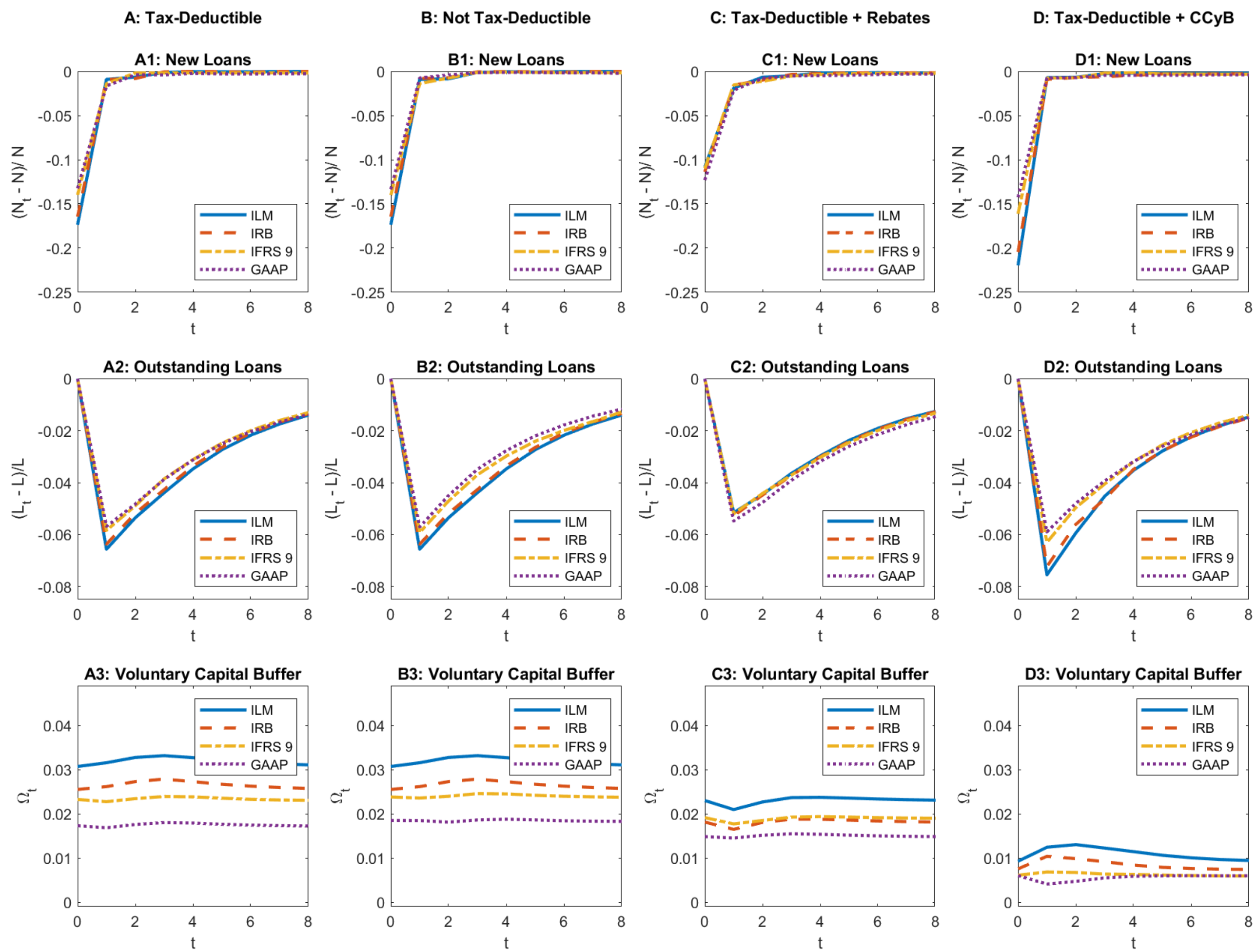

Figure 4. Effect of the Arrival of a Contraction on Loans and Capital under the Delayed Response of Profits.
This figure reports the generalized impulse response function of new loans N_t, outstanding loans L_t, and voluntary capital buffer Ω_t to the arrival of a contraction at $t = 0$, that is $s_0 = b$, when the bank's profits react with a one-period delay to the aggregate shock. Prior to the contraction the bank is in an expansionary aggregate state, $s_{-1} = g$, and its endogenous state is characterized by the unconditional mean, that is $L_0 = L := \mathbb{E}[L_t]$ and $\Omega_0 = \Omega := \mathbb{E}[\Omega_t]$. The impulse response functions are expressed in terms of relative deviation from the unconditional mean for new and outstanding loans (where $N := \mathbb{E}[N_t]$) and in levels for the voluntary capital buffer. We consider four scenarios: Panel A depicts the benchmark case in which the expected provisions under the ELM are tax-deductible and $\tau^- = 0$; Panel B depicts the case when the expected provisions are not tax-deductible under the ELM; Panel C assumed the tax-deductibility of expected provisions and relaxes loss limitations by setting $\tau^- = 0.10$; finally, in Panel D the expected provisions are tax-deductible and the bank must hold the Countercyclical Capital Buffer (CCyB). Each subfigure depicts four impulse response functions corresponding to the scenario when the bank operates under the Incurred Loss Model (ILM), the Internal Ratings-Based approach (IRB), the Expected Loss Model under IFRS 9 and the new US GAAP. The impulse response functions are obtained by averaging 250,000 simulated paths.

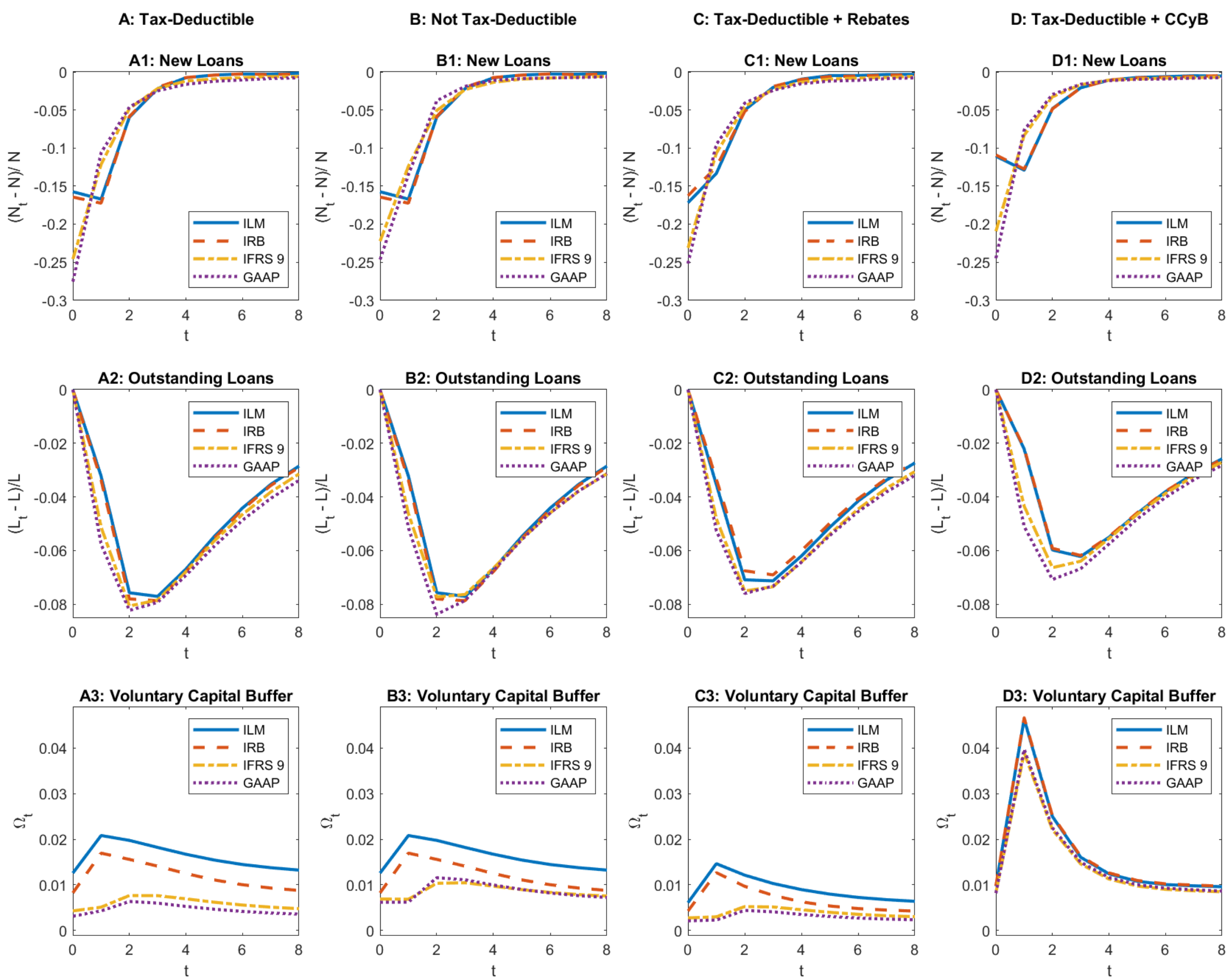

Figure 5. Effect of the Arrival of a Contraction on Default Probability under the Delayed Response of Profits.
This figure reports the generalized impulse response function of default rate to the arrival of a contraction at $t = 0$, that is $s_0 = b$, when the bank's profits react with a one-period delay to the aggregate shock. Prior to the contraction the bank is in an expansionary aggregate state, $s_{-1} = g$, and its endogenous state is characterized by the unconditional mean, that is $L_0 = L := \mathbb{E}[L_t]$ and $\Omega_0 = \Omega := \mathbb{E}[\Omega_t]$. We consider four scenarios: Panel A depicts the benchmark case in which the expected provisions under the ELM are tax-deductible and $\tau^- = 0$; Panel B depicts the case when the expected provisions are not tax-deductible under the ELM; Panel C assumed the tax-deductibility of expected provisions and relaxes loss limitations by setting $\tau^- = 0.10$; finally, in Panel D the expected provisions are tax-deductible and the bank must hold the Countercyclical Capital Buffer (CCyB). Each subfigure depicts four impulse response functions corresponding to the scenario when the bank operates under the Incurred Loss Model (ILM), the Internal Ratings-Based approach (IRB), the Expected Loss Model under IFRS 9 and the new US GAAP. The impulse response functions are obtained by averaging 250,000 simulated paths.