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CECL: Timely Loan Loss Provisioning and Bank Regulation

LUCAS MAHIEUX,* HARESH SAPRA,† AND GAOQING ZHANG‡

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ABSTRACT

We investigate how provisioning models interact with bank regulation to affect banks' risk-taking behavior. We study an accuracy versus timeliness trade-off between an incurred loss model (IL) and an expected loss model (EL) such as current expected credit loss model or International Financial Reporting Standards 9. Relative to IL, even though EL improves efficiency by prompting earlier corrective action in bad times, it induces banks to originate either safer or riskier loans. Trading off ex post benefits versus ex ante real effects, we show that more timely information under EL enhances efficiency either when banks are insufficiently capitalized or when regulatory intervention is likely to be effective. Conversely, when banks are moderately capitalized and regulatory intervention is sufficiently costly, switching to EL impairs efficiency. From a policy perspective, our analysis highlights the roles that regulatory capital and the effectiveness of regulatory intervention play in determining the economic consequences of provisioning models. EL spurs

*Tilburg University; †The University of Chicago; ‡The University of Minnesota

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haresh.sapra@chicagobooth.edu

credit supply and improves financial stability in economies where intervening in banks' operations is relatively frictionless and/or regulators can tailor regulatory capital to incorporate information about credit losses.

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1. Introduction

The recent adoption of expected loss models (ELs) for the estimation of credit losses for loans and debt securities, such as the current expected credit loss model (CECL) under ASU 2016-13 and the expected credit loss model (ECL) under the International Financial Reporting Standards (IFRS) 9, is arguably one of the most sweeping accounting changes to impact banks and financial institutions (Financial Accounting Standards Board [2019]). Under those changes, banks would replace an incurred loss model (IL) with an EL. A key difference between the two provisioning models is that under the IL, banks delay recognition of credit losses until they have been incurred, whereas under the EL, banks would estimate expected credit losses not only on the basis of past events and current conditions, but also on reasonable and supportable forecasts about the future, including future economic conditions. Although standard setters have argued that ELs would result in "more timely and relevant information," others have countered that it "could actually produce negative economic consequences" (Quaadman [2019]). Most notably, banks are concerned that the forecasts of future credit losses are often unreliable and false loss recognition may lower bank capital ratios and thereby "curtail credit availability, make credit losses worse during a recession and heighten volatility of bank earnings" (Maurer [2020]).[1] Despite this intense debate, somewhat surprisingly, relatively little is known about the exact mechanism through which loan loss provisioning interacts with prudential regulation to affect banks' behavior. In this paper, we develop an economic model to study the interaction between provisioning models and regulatory capital and examine how this interaction affects banks' risk-taking behavior.

We model a representative bank that is plagued by shareholder–debtholder conflicts. The bank's shareholders have incentives to take excessive risk by either: (1) increasing the ex ante risk of the bank's loan portfolio by exerting less effort to screen borrowers, and/or (2) engaging

[1] The COVID-19 crisis of 2020 is a case in point. There were concerns at the onset of the crisis that application of CECL during the crisis would severely erode banks' capital so that banks may curtail lending. In response, the CARES Act signed by President Trump on March 27, 2020 gave banks the option to delay implementing the new credit-loss standard until December 31, 2020, or until the end of the coronavirus national emergency, whichever came first.

in ex post asset substitution/risk-shifting to replace loans with high-risk assets. To discipline excessive risk-taking, a banking regulator imposes capital requirements. Importantly, the bank's level of capital depends on the provisioning model the bank uses to measure credit losses. Under an IL, the bank does not provision for credit losses until they are realized, whereas under the EL, the bank relies on early forecasts of default risk to provision for expected credit losses. Provisioning for expected credit losses erodes the bank's level of regulatory capital, that, in turn, triggers regulatory intervention. Upon intervention, the regulator decides whether to take any restructuring actions such as costly liquidation in order to preserve the expected surplus from the bank's loan portfolio. Regulatory intervention is effective, that is, the regulator chooses to liquidate the loan, if and only if the surplus gain from curbing asset substitution via liquidation outweighs the liquidation cost. Otherwise, regulatory intervention is ineffective as the regulator forbears the bank and fails to prevent it from engaging in inefficient asset substitution.

Fixing the bank's ex ante choices of loan risk, we show that timely loan loss provisioning under the EL always improves efficiency. Whenever the bank recognizes a loan loss in the interim, thereby eroding its regulatory capital, regulatory intervention prevents the bank from engaging in inefficient asset substitution. More importantly, we show that the benefit of timely loss recognition cannot be overturned by either frictions in regulatory intervention (e.g., costly liquidation) and/or the imprecision in the expected-loss information. The reason is that a rational and benevolent regulator fully internalizes these frictions when choosing whether to intervene.

However, once we allow for endogenous loan risk choices, early intervention is a double-edged sword. Although timely intervention curbs ex post risk-shifting, it may induce the bank to originate either safer or riskier loans. We find that—when regulatory intervention is more likely to be effective (i.e., the liquidation cost is relatively low)—timely intervention under expected loss generates dual benefits as it not only curbs ex post inefficient risk-shifting but it also enhances the bank's ex ante incentives to screen borrowers. We refer to this effect as the *risk-disciplining* effect of early intervention. Conversely, when the regulatory intervention is less likely to be effective (i.e., the liquidation cost is sufficiently high), the bank originates riskier loans under the EL. We refer to this effect as the *risk-aggravating* effect of early intervention. Such risk-aggravating effect results in a surplus loss that may outweigh the benefits of timely loss recognition, thereby potentially making the EL inferior to the IL.

To understand the risk-disciplining effect of early intervention, note that, under the EL, the regulator has a higher propensity to discipline the bank anticipating a stronger risk-shifting incentive. Furthermore, the bank's ex post incentive to substitute its loans with high-risk assets diminishes if it has exerted great screening effort ex ante and therefore originated high-quality loans. Recognizing these intertwined forces, the bank has an incentive to originate safer loans under expected loss in order to reduce the ex post likelihood of liquidation.

The risk-aggravating effect of early intervention is more subtle. As liquidation is costly, regulatory intervention is effective if and only if the surplus gain from liquidation outweighs the cost. The surplus gain arises from curbing asset substitution and preserving the surplus from the bank's loans. The gain is thus larger if the bank has originated safer loans with higher surplus. Anticipating this, the bank has an incentive to originate riskier loans ex ante in order to reduce the surplus of the loans as well as the gain from preserving it, thereby lessening the likelihood of liquidation.

In equilibrium, the bank trades off these two real effects in determining how much risk to take ex ante. We show that when the liquidation cost is sufficiently large (small), the risk-aggravating effect of early intervention dominates (is dominated by) its risk-disciplining effect, inducing the bank to originate riskier (safer) loans. Intuitively, the risk-aggravating effect is most prominent when the liquidation cost is significant so that the regulator is concerned that the surplus gain from curbing risk-shifting may not offset the cost. Anticipating the regulator's cost considerations, the bank responds by building up more risk in its loan portfolio ex ante that tilts the regulator's liquidation trade-off further to the cost side. In this sense, timely intervention triggers even timelier risk-taking by the bank.

The overall efficiency of the EL therefore depends on the trade-off between its ex post benefit of facilitating timely intervention and its real effects of disciplining/distorting the bank's ex ante risk-taking incentive. When liquidation cost is sufficiently low so that regulatory intervention is more likely to be effective, the ex ante real effects of switching to the EL are beneficial and reinforce its ex post benefit of curbing risk-shifting. This, in turn, makes the EL unambiguously better than the IL. Stated differently, considering the real effects of provisioning models, there are dual benefits of the EL relative to the benchmark case where the bank's ex ante choice of loan risk is held fixed.

Conversely, when liquidation cost is sufficiently high so that regulatory intervention is less likely to be effective, the real effects of adopting the EL reduce efficiency. Consequently, more timely information under the EL may no longer always improve surplus as one needs to trade off the detrimental ex ante real effects of the EL against its ex post benefit. Interestingly, we find that the expected loss model becomes inferior when regulatory intervention is likely to be ineffective (i.e., a high liquidation cost) and banks are moderately capitalized.[2] Intuitively, costly liquidation guarantees that ex ante, early intervention aggravates risk-taking. Moreover, when the bank's capital ratio is not too low, the ex post benefit of timely intervention

[2] When the bank is sufficiently capitalized, it will have no incentive to engage in risk-shifting in the first place. Accordingly, there is no need for the regulator to intervene under the EL so the bank surplus is identical under both provisioning models.

under the EL is relatively small as the bank's risk-shifting incentive has already been mitigated by the tight capital requirements. Combining these economic forces, the risk-aggravating effect dominates so that the EL becomes inferior when the liquidation cost is relatively large and the bank is moderately capitalized.

From a policy standpoint, a main insight from our model is that switching from an IL to an EL may not be a panacea: while it addresses risk-shifting concerns, it may still reduce financial stability—especially in economies where such risk-shifting problems are not too severe (e.g., banks are moderately capitalized) and regulatory intervention is not very effective. One may argue that as regulators have control over banks' capital ratios, they can potentially eliminate the adverse effects of ELs by adjusting the capital ratios optimally. We show that this is only true when regulatory intervention is relatively frictionless. In that case, by tailoring the bank's regulatory capital ratio to information about credit losses, the regulator can improve the efficiency of the EL. In particular, our model suggests that relative to regulatory capital under an IL, regulatory capital under an EL can be relaxed to spur credit supply when the liquidation cost is relatively small and the likelihood of recognizing large expected loan losses is high. But when regulatory intervention is relatively costly, the negative economic consequences of ELs cannot be overturned *even if* regulators have the full flexibility of tailoring the capital ratio to the provisioning model. In such economies, the most effective policy prescription for maintaining financial stability would be to shield the bank's capital from expected credit loss information. Our study of the interaction between capital requirements and accounting measurement rules hence echoes the recent call for better coordination between banking regulators and accounting standard setters.[3]

1.1 RELATED LITERATURE

Our paper contributes to the banking literature on financial reporting and accounting measurements. Given the extensive size of this literature, we refer interested readers to two surveys by Beatty and Liao [2014] and Acharya and Ryan [2016]. Most papers in this literature are empirical and study various aspects of accounting measurements and loan loss provisioning.[4] Our work is more related to empirical studies that examine the effect of loan loss provisioning on banks' risk-taking behavior. For example, Bushman and Williams [2012] document that timely recognition of

[3] The U.S. Congress recently recognized the importance of adjusting capital requirements in light of banks implementing CECL. It has directed the U.S. Treasury Department, in consultation with bank regulators, to study the impact of CECL and to determine whether any changes to regulatory capital requirements are necessary (Maurer [2020]).

[4] Beatty and Liao [2011] and Laux and Rauter [2017] study lending procyclicality. Akins, Dou and Ng [2017] analyze corruption in bank lending. Bischof, Laux, and Leuz [2021] focus on financial stability. Lopez-Espinosa, Ormazabal, and Sakasai [2021] and Lu and Nikolaev (2022) investigate informational effects.

expected future loan losses is negatively associated with risk-shifting. Similarly, Bushman and Williams [2015] find that delayed expected loan loss recognition is positively associated with banks' vulnerability to stock market liquidity risk, downside tail risk of individual banks and codependency of downside tail risk among banks. This empirical evidence is consistent with our model's prediction that timely recognition of loan losses always reduces ex post risk-shifting. However, the aforementioned studies do not separate banks' ex ante versus ex post risk choices while our model shows that distinguishing between these two risk choices is key to understanding the real effects of ELs. This is due to our model's main insight that as the liquidation cost of banks' portfolios becomes sufficiently high—so that regulatory intervention becomes less effective—timely loss recognition curbs ex post risk-taking but exacerbates ex ante risk-taking.

In this sense, our analytical framework offers some new and potentially sharper testable implications. In examining the real effects of loan loss provisioning, empirical researchers should distinguish between ex ante and ex post risk choices and classify banks' risk decisions by the time they are undertaken (e.g., screening effort at loan origination versus risk-shifting after learning bad news). Furthermore, to increase the statistical power of those tests, our model suggests that empirical researchers should partition the sample of banks into two subsamples: a subsample of banks holding portfolios with high liquidation costs and one with low liquidation costs. Our model then generates the following additional empirical hypothesis: *all else equal*, more timely loan loss recognition induces banks with high liquidation costs to originate riskier loans, whereas it induces banks with low liquidation costs to originate safer loans.

Our paper is related to the theoretical literature that examines the role of accounting measurements and disclosure in affecting financial stability and prudential regulation (see Goldstein and Sapra [2014] for a survey). For example, Allen and Carletti [2008], Plantin, Sapra, and Shin [2008], Burkhardt and strausz [2009], and Mahieux [2021] examine the impact of mark-to-market accounting on bank risk and financial stability. Corona, Nan, and Zhang [2019] examine the coordination role of stress-test disclosure in affecting bank risk-taking. Gao and Jiang [2018], Liang and Zhang [2019], and Zhang [2021] study the role of accounting measurements in stabilizing bank runs. Corona, Nan, and Zhang (2014) examine the effect of accounting information quality on the efficiency of capital requirements and banks' risk-taking incentives, taking into account the competition among banks. Heaton, Lucas, and Mcdonald [2010], Corona, Nan, and Zhang [2019], and Lu, Sapra, and Subramanian [2019] study the joint determination of optimal capital requirements policy and accounting rules.

Bertomeu, Mahieux, and Sapra (2022), hereafter BMS, is the closest theoretical study to ours. In both studies, the threat of regulatory intervention—triggered by accounting measurement jointly with regulatory capital requirements—affects banks' ex ante risk-taking incentives. BMS discuss the implications of their analyses for loan loss provisioning

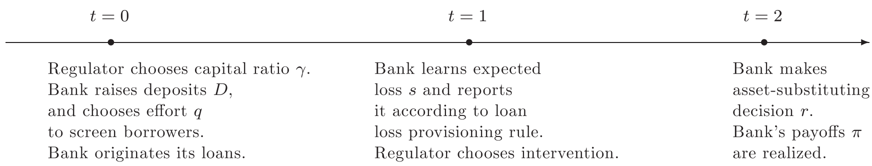

Fig 1.—Timeline of the model.

models, to the extent that imperfect interim measurement in BMS can be interpreted as an EL. In BMS, interim measurement allows the regulator to intervene and sell banks' assets when asset values deteriorate, similar to the role of ELs in our study. However, there are two important differences. First, in BMS, selling banks' assets is socially optimal if liquidation values exceed continuation values, whereas in our study, regulatory intervention *additionally* deters banks from inefficient ex post asset substitution. Second, in BMS, less precise measurement induces excessive regulatory intervention ex post and such excessive intervention has a positive ex ante disciplining effect on banks' risk-taking incentives. This, in turn, allows the regulator to relax capital requirements to spur bank lending. Unlike BMS, in our paper, while regulatory intervention always deters ex post inefficient asset substitution, its ex ante effect on banks' risk-taking incentives can be either positive or negative. In particular, we show that regulatory intervention may exacerbate ex ante risk-taking when excessive cost of intervention preempts effective discipline of banks holding riskier assets. Although the regulator may optimally adjust capital requirements to alleviate such negative ex ante effect, we show that such adjustments may not fully overturn the negative effect.

Section 2 describes our model. Section 3 analyzes the model. Section 4 concludes. Appendices A and B contain the proofs of our results and describes an implementation of loan loss provisioning in the context of our model.

2. *The Model*

2.1 TIMING OF EVENTS

We examine an environment that consists of a representative bank and a banking regulator. To focus on the conflict of interests between the bank's shareholders and debtholders (depositors), we assume that the bank's insiders acts in the best interests of the bank's shareholders: henceforth we simply refer to the "bank's shareholders" as the "bank." Figure 1 summarizes the timing of events.

At $t = 0$, the bank is endowed with an amount of exogenous level of equity $E > 0$. The regulator chooses a capital ratio $\gamma \in [\underline{\gamma}, 1]$, defined as the equity-to-asset ratio for the bank.[5] Given a fixed E, choosing the capital ratio γ is therefore equivalent to choosing the size A of the bank's loan portfolio or the bank size where $A \in [E, \bar{A}]$. $\bar{A} \equiv \frac{E}{\underline{\gamma}}$ denotes the maximum bank size and, for a fixed E, is inversely related to the minimum capital ratio $\underline{\gamma}$. We assume that $\underline{\gamma}$ is sufficiently small but strictly positive to impose an upper bound on the bank size. For a bank of size $A = \frac{E}{\gamma} \geq E$, the bank borrows $D = A - E$ from depositors. We assume that deposits are fully insured and we normalize the risk-free deposit rate to zero.

After raising deposits, the bank chooses costly effort $q \in [0, 1]$ to screen risky borrowers. The bank thereafter originates and invests A in a loan portfolio. The screening cost $AC(q)$ is proportional to the bank's size A and satisfies the following standard properties: $C(0) = 0$, $C(1) = \infty$, $C'(0) = 0$, $C'(1) = \infty$, and $C'' > 0$. The outcome of the loan is binary: either the loan succeeds or it defaults. Conditional on screening effort q, the loan returns $\alpha > 1$ with probability $\widetilde{s} + (1 - \widetilde{s})q$ and 0 with probability $1 - [\widetilde{s} + (1 - \widetilde{s})q]$. Note that this specification of the return structure guarantees that the bank's screening effort q improves the quality of the loan portfolio by reducing the default risk. In addition, the default risk also depends on a state variable $\widetilde{s}$, which has a distribution $H(.)$ and a density $h(.)$ with full support on $[\underline{s}, 1]$, where $\underline{s} > 0$ represents a lower bound on the success probability of the loan.

At $t = 1$, the bank privately observes the realization of the early credit-loss information s. The arrival of such information alters the bank's assessment of the default likelihood and future loan losses. In this light, we interpret s as some *early but imprecise* information about a nonincurred loan value change that arrives at the intermediate date, and reflects the change in expectation of future loan losses. An important goal of our model is to study the economic consequences of timely loan loss provisioning under an EL such as CECL or IFRS 9. We study two provisioning models. We refer to the model in which the bank does not provision for loan losses until the terminal loan payoffs are realized as an "incurred loss model (IL)" and the model in which the bank additionally uses the early information s to provision for loan losses early as an "expected loss model (EL)." Relative to the IL, the EL thus recognizes *a more timely but potentially imprecise estimate* of expected loan losses.

The timely recognition of loan losses facilitates early regulatory intervention in the bank. In particular, under the IL, because the bank delays

[5] We consider the case that the regulator uses a simple leverage ratio to regulate capital. This is consistent with the newly proposed Basel III framework. In particular, Section V of Basel Committee [2010] provides a discussion of the use of leverage ratios in Basel III, that "the Committee agreed to introduce a simple, transparent, non-risk based leverage ratio that is calibrated to act as a credible supplementary measure to the risk based capital requirements." However, we do not explicitly study the exact implementation of the regulatory leverage requirements, which, in reality, could be achieved via minimum capital requirements, comprehensive capital analysis and review (CCAR), and other regulatory intervention actions.

the recognition of loan losses, its capital ratio stays the same as $t = 0$, thus providing no basis/triggers for regulatory intervention. In contrast, under the EL, timely recognition of loan losses at $t = 1$ leads to a write-down of the bank's loan, which, in turn, lowers its capital ratio. The erosion of the capital ratio, in turn, prompts regulatory intervention.[6] In practice, upon intervention, a regulator has broad discretion in terms of what actions to take ranging from being passive, thereby allowing the bank to continue its operations to a reorganization, partial asset sale, a reduction in the scope of the bank or even liquidation. For simplicity, we focus on two possible actions: continuation or liquidation.[7] Upon intervention, we assume that the regulator learns both the quality q and state s of the loan and shares this information publicly with market participants when choosing to liquidate/sell the loan. Given s and q, the regulator optimally liquidates the bank's loan if the expected payoffs from liquidation exceed the expected payoffs from continuation. If the regulator decides to liquidate, the operation of the bank is terminated and each unit of the bank's loans is liquidated at the expected value of the terminal payoffs π, that is,

$$L = E\left[\widetilde{\pi} | s, q\right], \tag{1}$$

subject to a liquidation cost $AK \geq 0$. The liquidation cost is proportional to the bank's size and can be interpreted as either the cost of selling the loans in illiquid secondary loan market (e.g., Plantin, Sapra, and Shin [2008]), or the nonpecuniary costs the regulator incurs in the process of closing/restructuring the bank (e.g., Bennett and Unal [2015]). We will later refer to the liquidation cost K as the (in)effectiveness/frictions in regulatory intervention. Given a large liquidation cost, the regulator will be forced to forbear the bank even when anticipating the bank's subsequent inefficient asset substitution incentive. In this sense, a higher liquidation cost makes regulatory intervention less effective in disciplining asset substitution. Conversely, when the liquidation cost becomes smaller, the regulator is more likely to liquidate the loan upon intervention (when it is optimal to do so), and hence regulatory intervention is more likely to be effective. For simplicity, we assume that upon liquidation, the bank's shareholders receive zero payoff. This assumption is consistent with the practice

[6] In Appendix B, we provide a detailed account on the implementation of loan loss provisioning and its impact on a bank's balance sheet and its capital ratio. In particular, we illustrate how provisioning for loan losses triggers regulatory intervention under the EL but not under the IL.

[7] The structure of ex post intervention actions (continuation vs. liquidation) that our model adopts follows directly from the continue-stop modeling structure ("C" vs. "S") developed in the seminal work of Dewatripont and Tirole [1994a]. For convenience, we refer to the action that reduces the risk of the bank's loans as "liquidation." Note, however, that this action is not only limited to liquidating the bank's loans, but may also be broadly interpreted as any action that makes the terminal cash flows of the loans less volatile and more deterministic, for instance, restructuring the bank's loan portfolio, and so on.

that in case of bank closure, banks' shareholders recover relatively little residual value.

At $t = 2$, in case of continuation, based on its updated assessment of the loan performance, the bank may choose to engage in risk-shifting/asset substitution by choosing $r \in \{0, 1\}$. The variable $r = 0$ implies no asset substitution so that the bank does not change its original loan portfolio, whereas the variable $r = 1$ implies that the bank changes its original loan portfolio by substituting it with a high-risk asset. The high-risk asset returns β with probability τ and 0 with probability $1 - \tau$. We assume that $\tau \in (0, \underline{s})$ so that the high-risk asset always has a higher default risk (lower success probability) than the bank's original loan portfolio. To reflect the risk–return trade-off, we assume that $\beta > \alpha > 1$ such that the high-risk asset yields a higher investment return upon success.

After the bank's asset substitution decision, its terminal payoffs are realized. The per-unit payoff π from the bank is as follows. If the bank's loan is liquidated, $\pi = L$, whereas in the case of continuation, $\pi = \alpha$ with probability $s + (1 - s)q$ and $\pi = 0$ with probability $1 - [s + (1 - s)q]$. But, if the bank engages in asset substitution, $\pi = \beta$ with probability τ and $\pi = 0$ with probability $1 - \tau$. The regulator compensates depositors if the bank fails, that is, $\pi < D$, with a lump sum payment which we assume is financed via a frictionless ex ante tax.

2.2 ASSUMPTIONS

To highlight the role of prudential regulation and its interaction with provisioning models, we impose the following assumptions (A1–A7) throughout our entire analysis.

Assumption 1. *The regulator cannot commit to a specific intervention action.*

This assumption is consistent with the practice of prudential regulation (see, e.g., Dewatripont and Tirole [1994a]). For instance, in the United States, the Federal Reserve only sets capital requirements ratios (e.g., to be well-capitalized, a bank holding company must have a Tier-1 capital ratio of 6%) but never firmly specifies any intervening action. Such lack of commitment by banking regulators has been examined extensively in the literature (e.g., Bagehot [1873]; Mailath and Mester [1994]; Freixas [1999]). Accordingly, we assume that, after the bank violates its regulatory capital constraint, the regulator chooses the ex post optimal action when intervening. Note that similar assumptions are commonly employed in the prudential regulation literature (e.g., Dewatripont and Tirole [1994a]) and the debt contracting literature (e.g., Dewatripont and Tirole [1994b]).

Assumption 2. *The opportunity of asset substitution arises only after the arrival of the expected-loss information s.*

This assumption creates a demand for early regulatory intervention based on the timely recognition of expected loan losses *before* the bank takes an inefficient action. Otherwise, if the bank is allowed to engage in asset substitution at $t = 0$, the benefit of timely loan loss recognition in curbing inefficient bank actions would become less prominent.

Assumption 3. *The regulator can only intervene upon a violation of the capital requirements constraint.*

This assumption allows us to focus exclusively on the important role that provisioning models would play in affecting regulatory capital. It is broadly consistent with the practice of prudential regulation. For example, in the United States, the Federal Deposit Insurance Corporation (FDIC) classifies banks into different capital categories (e.g., well-capitalized, undercapitalized, etc.) and tailors supervisory actions to each category (§325.103, Subpart B, FDIC, 2021).[8]

Assumption 4. *Asset substitution is value-destroying and after asset substitution, the bank's assets yield a lower net present value (NPV).*

This assumption ensures that the regulator has an incentive to discipline the bank from engaging in asset substitution. It turns out that Assumption 4 is reduced into

$$\tau\beta < \min(\underline{s}\alpha, 1). \tag{2}$$

Assumption 5. *The liquidation cost is not excessive such that upon intervention, the regulator may choose to liquidate the bank.*

This assumption rules out the uninteresting scenario in which the liquidation cost is so large that regulatory intervention is always ineffective in the sense that the regulator will always forbear the bank. It turns out that a sufficient condition for Assumption 5 is

$$K < \alpha - \tau\beta. \tag{3}$$

Assumption 6. *The bank always prefers to asset-substitute at its maximum leverage, that is, $\gamma = \underline{\gamma}$.*

This assumption rules out the degenerate case in which the bank will never engage in inefficient asset substitution even when choosing the highest

[8] Under certain circumstances, the regulator may have some discretion to act independently of the measurement of bank capital. This occurs because "(t)he FDIC may reclassify a well-capitalized bank as adequately capitalized and may require an adequately capitalized bank or an undercapitalized bank to comply with certain mandatory or discretionary supervisory actions as if the bank were in the next lower capital category" (§325.103 (5d), Subpart B, FDIC, 2021). There are, however, important limits to such regulatory discretion. First, "the FDIC may not reclassify a significantly undercapitalized bank as critically undercapitalized," which would typically trigger the most severe form of intervening actions (§325.103 (5d) and §325.105 (4), Subpart B, FDIC, 2021). Second, prior to any reclassification, the FDIC "shall issue and serve on the FDIC-supervised institution a written notice of the FDIC's intention to reclassify it," and "the FDIC-supervised institution subject to the notice of reclassification may file with the FDIC a written appeal of the proposed reclassification and a request for a hearing" (§308.202, Subpart Q, FDIC, 2021).

leverage and borrowing to the maximal extent. When $\underline{\gamma}$ is sufficiently close to 0, this assumption reduces to

$$\alpha - 1 < \tau(\beta - 1). \tag{4}$$

Assumption 7. *The regulator learns the quality of the loan q at the intervention stage and shares this information with market participants.*

This assumption is generally consistent with the practice of bank resolution and restructuring, during which bank examiners learn the quality of the loans when they conduct on-site inspections of banks' loan portfolios. In addition, inspected banks are often forced to recognize and report the lower quality of their credit portfolios, which reveals a considerable amount of information about the loan quality to regulators as well as other market participants.[9]

3. *Analysis*

We solve the model using backward induction.

3.1 ASSET SUBSTITUTION/RISK-SHIFTING DECISION

At $t = 2$, the bank has the option to engage in asset substitution either under the IL in which the bank delays the recognition of the expected-loss information s so that the regulator cannot intervene, or under the EL in which the regulator intervenes but remains passive by not liquidating the bank. We denote the expected payoff of bank's shareholders by $U(r, q|s)$. If the bank chooses not to engage in asset substitution $(r = 0)$, its payoff is

$$U(0, q|s) = \left[s + (1 - s)q\right]\left[\alpha - (1 - \gamma)\right]A. \tag{5}$$

The bank receives a net payoff of $A\alpha - (A - E)$ after repaying depositors with probability $s + (1 - s)q$, and receives 0 otherwise. Using $\gamma \equiv \frac{E}{A}$ and taking the expectation of the bank's payoff yields (5).

If the bank engages in asset substitution so that $r = 1$, its payoff is

$$U\left(1, q|s\right) = \tau\left[\beta - (1 - \gamma)\right]A. \tag{6}$$

Conditional on asset substitution, the bank receives $A\beta - (A - E)$ after repaying depositors with probability τ, and receives 0 with probability $1 - \tau$.

[9] Passalacqua et al. [2021] study the "random audits" of Italian mutuals by bank supervisors. They empirically document an interesting "information disclosure effect" in which audited banks are forced to reclassify loans as nonperforming. Bonfim et al. [2020] study the on-site inspection of Portuguese banks by bank regulators. They report that "(t)he main goal of the inspections was to validate the quality of assets that the banks were using as inputs for their regular risk assessments. These validation exercises implied an unprecedented level of intrusion, since the inspectors analyzed a large number of individual credit files of the inspected banks and had the freedom to collect additional information from the borrowers themselves."

Using $\gamma \equiv \frac{E}{A}$ and taking the expectation yields (6). Note that as the bank's payoff from asset substitution $U(1, q|s)$ does not depend on either the bank's initial risk choice q or the state variable s, to economize on notation, we hereafter omit $\{q, s\}$ in $U(1, q|s)$ and simply denote it by $U(1)$. The bank therefore chooses asset substitution if and only if

$$U(1) > U(0, q|s), \tag{7}$$

which reduces into

$$\tau\big[\beta - (1-\gamma)\big] > \big[s + (1-s)q\big]\big[\alpha - (1-\gamma)\big]. \tag{8}$$

The left-hand side of (8) represents the bank's payoff from asset substitution and does not depend on s. As s increases, the success probability of the bank's loan increases so that the right-hand side of (8) that represents the bank's payoff from investing in its original loan strictly increases in s. As a result, there exists a unique cutoff s_B such that the bank engages in asset substitution if and only if early information regarding its loan's performance is below the cutoff, that is, $s < s_B$. We next formally state the bank's equilibrium asset-substituting decision.

Proposition 1. *Given the bank's screening effort q and the capital ratio γ, there exists a unique threshold $s_B \in [\underline{s}, 1]$ such that the bank makes the asset-substituting decision $(r = 1)$ if and only if $s < s_B$. The threshold s_B depends on γ as follows*

$$\begin{cases} s_B = 1 & \text{if } \gamma \in [\underline{\gamma}, \gamma_{\min}]; \\ s_B = \frac{\tau}{1-q}\frac{\beta-(1-\gamma)}{\alpha-(1-\gamma)} - \frac{q}{1-q} & \text{if } \gamma \in (\gamma_{\min}, \gamma_{\max}(q)); \\ s_B = \underline{s} & \text{if } \gamma \in [\gamma_{\max}(q), 1]. \end{cases} \tag{9}$$

The cutoffs $\gamma_{\min} \equiv \frac{\tau(\beta-1)-(\alpha-1)}{1-\tau} \in (\underline{\gamma}, 1)$ and $\gamma_{\max}(q) \equiv \frac{\tau(\beta-1)-(q+(1-q)\underline{s})(\alpha-1)}{q+(1-q)\underline{s}-\tau} \in (\gamma_{\min}, 1)$. Ceteris paribus, the threshold s_B decreases in both the screening effort q and the capital ratio γ for $s_B \in (\underline{s}, 1)$.

Proposition 1 is intuitive: whenever the bank expects the performance of its loan portfolio to deteriorate, its incentives to engage in asset substitution increase and those incentives sharpen as the bank's capital ratio γ decreases. This result suggests a beneficial role for regulatory capital ratios in curbing asset substitution: a higher capital ratio γ weakens the bank's asset-substituting incentives in the interim. When the bank's capital ratio is sufficiently large, it never engages in asset substitution, whereas whenever the bank's capital ratio is sufficiently low, it always chooses to asset-substitute. For intermediate values of capital ratios, the bank's assessment of its loan performance matters and the bank engages in asset substitution if and only if such assessment deteriorates.

Interestingly, Proposition 1 also points to a complementary relationship between the bank's ex ante risk decision (screening) and ex post risk decision (asset substitution). Ceteris paribus, the bank's incentive to engage in inefficient asset substitution diminishes if it has exerted greater screening effort and therefore originated loans of higher quality, that is, s_B decreases in q. This is intuitive as the bank derives a greater payoff from keeping higher quality loans, and thus is less tempted to substitute them with the high-risk asset. An empirical implication of this result is that, absent regulatory intervention, banks' risk profile over the terms of their loans is serially correlated in the sense that banks originating riskier loans are more likely to engage in risk-shifting when their loans underperform.

3.2 REGULATORY INTERVENTION AND LIQUIDATION

We next analyze the regulator's intervention and liquidation decision at $t = 1$ under the EL where, as shown in Appendix B, early recognition of expected loan losses triggers the violation of capital requirements and prompts the regulator to intervene. Upon intervention, three key factors come into play in determining the regulator's liquidation decision: (1) the information s, (2) the bank's ex ante screening choice q, and (3) the bank's future asset-substituting decision r. More specifically, if $s \geq s_B$, the regulator rationally anticipates that the bank will keep the original loan, whose per-unit expected surplus is

$$E\left[\pi|s, q\right] > L - K = E\left[\pi|s, q\right] - K. \tag{10}$$

That is, absent the asset substitution problem, the regulator should remain passive and never liquidate the bank early based on the timely but imperfect information s, because liquidating the bank only recovers the expected surplus from the bank's loan but entails a liquidation cost, resulting in a lower net surplus than the surplus from continuation. We summarize this result in the following lemma.

Lemma 1. *If the interim information $s \geq s_B$ (i.e., the bank does not asset-substitute), the regulator should never liquidate the bank at the intervention stage. The threshold s_B is defined in Proposition 1.*

Lemma 1 suggests that, absent the bank's asset substitution incentive ($s \geq s_B$), the issue of early regulatory intervention—and therefore its effectiveness—is moot as the regulator should always remain passive even when given the opportunity to intervene. Conversely, when $s < s_B$, the regulator faces a nontrivial trade-off in intervening early in the bank's operations. On the one hand, anticipating the bank's propensity to asset-substitute, the regulator has an incentive to liquidate the bank in order to curb such risk-shifting behavior. On the other hand, however, when liquidation is costly, the regulator may be forced to forbear the bank despite its subsequent asset-substituting decision. In this sense, regulatory intervention may cease to be *effective* in disciplining inefficient asset substitution due to the friction/cost in the intervention process.

To elaborate on this trade-off of regulatory intervention, note that when the loan performance deteriorates, that is, $s < s_B$, the regulator anticipates that the bank will substitute its loans with the high-risk asset, which generates an expected surplus of $\tau\beta$. Such risk-shifting, in turn, results in an expected surplus loss relative to the expected surplus that the bank's loan could have generated had the loan not been substituted, which is given by

$$E\big[\pi|s, q\big] - \tau\beta = \big[s + (1-s)q\big]\alpha - \tau\beta > 0. \tag{11}$$

The last inequality uses (2). In equilibrium, the regulator liquidates the loan if and only if the expected surplus loss from asset substitution exceeds the liquidation cost. Stated differently, regulatory intervention is effective if and only if the asset substitution surplus loss outweighs the liquidation cost, that is, whenever

$$\big[s + (1-s)q\big]\alpha - \tau\beta > K. \tag{12}$$

We formally state the regulator's liquidation decision at $t = 1$ in the following proposition.

Proposition 2. *Given the bank's screening choice q and the capital ratio γ, upon intervention, the regulator's equilibrium liquidation decision in the EL is as follows:*

1) *When $q \geq \frac{K-(\underline{s}\alpha-\tau\beta)}{\alpha(1-\underline{s})}$, the regulator liquidates the bank if and only if the bank engages in asset substitution, that is, whenever $s < s_B$.*
2) *But when $q < \frac{K-(\underline{s}\alpha-\tau\beta)}{\alpha(1-\underline{s})}$, the regulator liquidates the bank if and only if $s \in (s_L, s_B)$, where the liquidation threshold*

$$s_L \equiv \frac{1}{1-q}\frac{\tau\beta + K}{\alpha} - \frac{q}{1-q}, \tag{13}$$

and the threshold s_B is defined in Proposition 1. Ceteris paribus, s_L increases in the liquidation cost K and decreases in the screening effort q.

Proposition 2 identifies three key determinants of the regulator's liquidation decision: the liquidation cost K, the early information s, and the bank's ex ante screening effort q. The role of the liquidation cost K is intuitive. Ceteris paribus, a higher liquidation cost shrinks the region of s in which the bank is liquidated. In fact, a direct implication of Proposition 2 is that when liquidation is excessively costly, regulatory intervention is ineffective because, even when anticipating the bank's asset substitution incentive, the regulator chooses to forbear the bank and hence fails to prevent it from engaging in asset substitution.[10]

When the liquidation cost is relatively low, two economic forces come into play. First, liquidating the bank at a cost is efficient only when the loan performance deteriorates, that is, $s < s_B$, such that the bank has an incentive to engage in asset substitution. Second, expression (12) suggests that the gain from curbing asset substitution outweighs the liquidation cost only when the surplus from the bank's loan is sufficiently large, that is, either the bank has originated high-quality loans (high q) or its loans outperform

[10] Mathematically, the proof of Corollary 1 shows that the regulator never liquidates the bank if $\gamma \geq \frac{\tau(\beta-\alpha)-K(\alpha-1)}{\tau(\beta-\alpha)+K}$, which holds when K is sufficiently large.

$(s > s_L)$. When loan quality is sufficiently high, (12) is always met; therefore, the regulator will liquidate the bank whenever the bank has an incentive to asset-substitute. However, when the bank exerts less screening effort, the regulator's incentive to liquidate the loan decreases (s_L increases) as the gain from preserving the surplus from the bank's loan via costly liquidation diminishes. Consequently, the regulator will liquidate the bank only when the interim signal $s \in (s_L, s_B)$: on the one hand, s is low enough such that absent intervention, the bank would engage in inefficient asset substitution; on the other hand, s must also be sufficiently high such that the net gain from continuing the bank's loans offsets the liquidation cost.

Interestingly, Proposition 2 also implies a negative association between the bank's capital ratio and the regulator's propensity to liquidate the bank given that a higher capital ratio γ reduces the asset substitution threshold s_B (Proposition 1) and makes liquidation less likely. In fact, if the bank is sufficiently capitalized, the regulator will never liquidate the bank under the EL. This result is intuitive: a sufficiently capitalized bank has little incentive to engage in asset substitution ex post so that the surplus gain of liquidation stemming from curbing asset substitution is minimal and thus insufficient to cover the liquidation cost. Consequently, the regulator remains passive and always continues sufficiently capitalized banks even if recognition of expected loan losses erodes their capital. Absent regulatory intervention, expected loss yields the same equilibrium outcome as incurred loss. We formally state these results in the following corollary.

Corollary 1. *There exists a cutoff*

$$\gamma_1 \equiv \frac{\tau(\beta-\alpha) - K(\alpha-1)}{\tau(\beta-\alpha)+K} \in (\gamma_{\min}, 1),$$

such that if the capital ratio $\gamma \geq \gamma_1$, the regulator never liquidates the bank under the EL and the equilibrium outcomes are identical across the expected and the ILs.

Although Proposition 2 implies that early regulatory intervention may sometimes be ineffective, one might conjecture that, holding fixed the quality of the bank's loan portfolio, timely recognition of loan losses under the EL should still be beneficial as long as the regulator acts on the additional information optimally. The following corollary confirms such a conjecture, which is also illustrated in figure 2.

Corollary 2. *Given the bank's screening choice q and the capital ratio γ, the EL always dominates the IL.*

Corollary 2 implies that the early information revealed by the expected loan loss model generates an expected benefit because it allows regulators to intervene in a more timely manner in banks' operations to curb inefficient asset substitution. Interestingly, such benefit cannot be overturned by either frictions in regulatory intervention (e.g., the liquidation cost) or the imprecision in the expected-loss information, thereby making accuracy versus timeliness trade-off one-sided. The preceding result hence

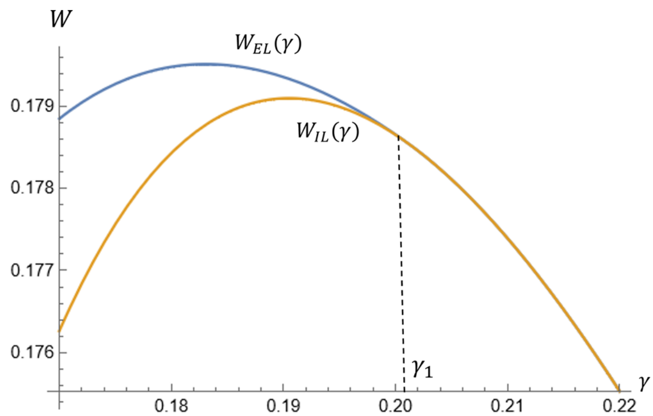

FIG 2.—Surplus comparison between the expected loss and the incurred loss models, W_{EL} and W_{IL}, as a function of the capital ratio γ, holding fixed the bank's screening choice q. The following parameter values are used in this plot: $\alpha = 1.1$, $\beta = 9/8$, $K = 0.058$, $\underline{s} = 0.9$, $\tau = 7/8$, and $q = 0.1$. Note that for $\gamma \geq \gamma_1 = 0.201$, $W_{EL} = W_{IL}$.

supports claims made by proponents of ELs who have argued that by providing more timely information about the performance of banks' loans, ELs would prompt earlier corrective action in bad times. Corollary 2 confirms those views and shows that ELs dominate ILs *as long as the ex ante risk of the banks' loan portfolios is kept fixed.* However, as we show next, banks are not passive technologies—rather banks' management would respond to the regulator's intervention strategy by changing banks' lending behavior.

3.3 EX ANTE RISK DECISION

We now analyze the bank's choices of the riskiness q of the loans at the origination stage under the two loan loss models.

3.3.1. Ex Ante Risk Under Incurred Loss. We start with the IL. For a given capital ratio γ, the bank chooses risk q that solves

$$q^*_{IL} \in \arg\max_{q\in[0,1]} \underbrace{\int_{\underline{s}}^{s_B} U(1)\,h(s)\,ds}_{\text{expected payoff given asset substitution}} + \underbrace{\int_{s_B}^{1} U(0, q|s)\,h(s)\,ds}_{\text{expected payoff given no asset substitution}} - AC(q). \tag{14}$$

Recall that if $s < s_B$, the bank's payoff is independent of its initial risk choice because the bank will engage in asset substitution and replace the loan portfolio with the high-risk asset. Thus, the ex ante risk choice only matters when the bank does not asset-substitute. The higher the likelihood of interim asset substitution, the lower the bank's incentives to engage in costly ex ante screening, that is, q^*_{IL} decreases in s_B. From Proposition 1, as the bank's leverage becomes very large, that is, $\gamma \in [\underline{\gamma}, \gamma_{\min}]$ so that $s_B = 1$, the bank always engages in interim asset substitution making the ex ante risk decision moot. In this case, because screening is costly, the bank chooses not to screen the borrowers ex ante so that $q^*_{IL} = 0$.

Taking the first-order condition of the preceding equation with respect to q and recognizing that $U(1) = U(0, q|s_B)$ yields

$$\int_{s_B}^{1} \frac{\partial U\big(0, q|s\big)}{\partial q} h(s)\, ds = AC'\big(q^*_{IL}\big). \tag{15}$$

The right-hand side of equation (15) captures the marginal cost of screening borrowers, whereas the left-hand side captures the marginal benefit of screening stemming from reducing the future default risk. To see the latter effect, note that from equation (5),

$$\frac{\partial U\big(0, q|s\big)}{\partial q} = (1 - s)\big[\alpha - (1 - \gamma)\big]A, \tag{16}$$

is the marginal improvement in the loan success probability from more screening, multiplied by the bank's net profit upon loan success.

We formally state the bank's ex ante risk choice in the following proposition.

Proposition 3. *Under the IL, the bank chooses risk q^*_{IL} such that, for $\gamma \in [\underline{\gamma}, \gamma_{\min}]$, $q^*_{IL} = 0$, whereas for the capital ratio $\gamma \in (\gamma_{\min}, 1]$, $q^*_{IL} \in (0, 1)$ and solves equation (15). Ceteris paribus, the risk choice q^*_{IL} increases in the capital ratio γ.*

3.3.2. Ex Ante Risk Under Expected Loss. Under the EL, the bank chooses risk q that solves

$$q^*_{EL} \in \arg\max_{q \in [0,1]} \underbrace{\int_{\underline{s}}^{s_L} U(1)\, h(s)\, ds}_{\text{expected payoff given no liquidation}} + \underbrace{\int_{s_B}^{1} U(0, q|s)\, h(s)\, ds}_{\text{expected payoff given no asset substitution}} - AC\big(q\big). \tag{17}$$

Note that when $s < s_B$, the bank's expected payoff under the EL differs from that under the IL in (14). Under the EL, low values of s result in loan losses triggering regulatory intervention. Such intervention may or may not prevent the bank from engaging in asset substitution. From Proposition 2, the regulator remains passive whenever regulatory intervention is ineffective (i.e., whenever $s < s_L$), in which case the bank substitutes its loans with the high-risk asset and receives $U(1)$.

Taking the first-order condition with respect to q and recognizing that $U(1) = U(0, q|s_B)$ yields

$$\int_{s_B}^{1} \frac{\partial U\big(0, q|s\big)}{\partial q} h(s)\, ds - \frac{\partial P_L^*}{\partial q} U(1) = AC'\big(q_{EL}^*\big), \tag{18}$$

where P_L^* denotes the equilibrium probability that the regulator liquidates the bank's loans upon intervention.[11] Similar to the first-order condition under incurred loss, the right-hand side of equation (18) represents the marginal screening cost, whereas the left-hand side captures the marginal screening benefit. The first term on the left-hand side is also present in the first-order condition (15) under incurred loss and represents the effect of screening in reducing future default risk of the bank's loans. The second term captures an additional effect of screening under expected loss that is absent in the IL. From Proposition 2, the regulator optimally adjusts the liquidation strategy P_L^* to the bank's loan quality, which, in turn, depends on the bank's ex ante screening decision. Anticipating this, the bank acquires an incentive to vary its ex ante screening decision, from what it would choose under incurred loss, in order to deter liquidation. In this light, the accounting shift from incurred loss to expected loss generates *real effects* in the sense that adopting an EL to measure loan losses affects the very quality of loans that banks originate. Characterizing such real effects is a key focus of our study and requires us to analyze the first-order condition (18) in detail. Unfortunately, solving (18) under a general distribution of s is analytically intractable. To gain sharper insights, we hereafter make the simplifying assumption that s is uniformly distributed in $[\underline{s}, 1]$. Under this specification, we formally state the real effects of adopting the EL on the bank's ex ante risk choice in the following proposition.

Proposition 4. *Under the EL, for a given capital ratio γ and liquidation cost K, the bank chooses risk q_{EL}^* that solves equation (18) such that*

1. *if the capital ratio $\gamma \in [\underline{\gamma}, \gamma_{\min}]$, $q_{EL}^* = q_{IL}^* = 0$;*
2. *if the liquidation cost $K \leq \underline{s}\alpha - \tau\beta$, the bank originates riskier loans under incurred loss than under expected loss, that is, $q_{EL}^* \geq q_{IL}^*$;*
3. *if the liquidation cost $K \in (\underline{s}\alpha - \tau\beta, \overline{K})$, the bank originates riskier loans under expected loss than incurred loss, that is, $q_{EL}^* < q_{IL}^*$ if and only if the capital ratio $\gamma \in (\gamma_{\min}, \gamma_0)$, where the cutoffs $\gamma_0 \leq \gamma_1$ and $\overline{K} > \underline{s}\alpha - \tau\beta$ are defined in appendix A;*
4. *if the liquidation cost $K \geq \overline{K}$, the bank originates riskier loans under expected loss than incurred loss, that is, $q_{EL}^* \leq q_{IL}^*$.*

[11] From Proposition 2, the liquidation probability $P_L^* = H(s_B)$ if $q_{EL}^* \geq \frac{K-(\underline{s}\alpha-\tau\beta)}{\alpha(1-\underline{s})}$ and $P_L^* = H(s_B) - H(s_L)$ if $q_{EL}^* < \frac{K-(\underline{s}\alpha-\tau\beta)}{\alpha(1-\underline{s})}$, where $H(.)$ is the cumulative distribution of s. In the proof of Proposition 4, we provide detailed analysis of the first-order condition (18) under all cases.

Proposition 4 implies that when real effects are taken into account, timely intervention under expected loss is a double-edged sword: it always curbs ex post asset substitution but it may induce the bank to originate safer or riskier loans. In particular, switching to the EL aggravates (disciplines) ex ante risk-taking when the liquidation cost is sufficiently large (small). But when the liquidation cost is intermediate, then expected loss aggravates risk-taking if and only if the bank's capital ratio is moderately low.

To understand the risk-disciplining and risk-aggravating effects, we compare the first-order condition (15) on q^*_{IL} with the first-order condition (18) on q^*_{EL}. Note that $q^*_{EL} \leq q^*_{IL}$ if and only if the additional term on the left-hand side of (18) is negative, that is, $\frac{\partial P^*_L}{\partial q} \geq 0$. Intuitively, if higher screening effort increases (decreases) the likelihood of liquidation, the bank would respond by spending less (more) effort to screen borrowers, which generates a risk-aggravating (risk-disciplining) effect under expected loss. Consequently, whether early intervention disciplines/aggravates ex ante risk-taking hinges on how the bank's ex ante choice affects P^*_L, the regulator's propensity to liquidate the bank's loans. Proposition 2 suggests that, depending on the size of the liquidation cost and the level of the bank's capital ratio, two economic forces can be at play.

The first force works through the interaction between the bank's ex ante risk choice and ex post asset substitution decision. To illustrate, consider the first scenario of Proposition 2 in which the gain from curbing asset substitution always outweighs the liquidation cost (i.e., $q^*_{EL}(\gamma) \geq \frac{K-(\underline{s}\alpha-\tau\beta)}{\alpha(1-\underline{s})}$) such that the regulator intervenes and liquidates the bank's loans anticipating the bank's asset substitution incentive. This occurs when either the liquidation cost is sufficiently low (low K) or the bank's loan quality is superior (high q^*_{EL}). The latter holds in equilibrium when the bank is sufficiently capitalized. Furthermore, recall from Proposition 1 that there is a complementary relationship between the bank's screening and asset substitution decisions. This implies that higher screening effort disciplines the bank from engaging in asset substitution that, in turn, mitigates the likelihood of liquidation. Recognizing these intertwined forces, the bank has an incentive to originate safer loans under expected loss in order to reduce the ex post likelihood of liquidation.

To illustrate the risk-aggravating effect, consider the second scenario of Proposition 2 when the liquidation cost is sufficiently high/or the bank's loan is of inferior quality (i.e., $q^*_{EL}(\gamma) < \frac{K-(\underline{s}\alpha-\tau\beta)}{\alpha(1-\underline{s})}$). In this case, the regulator is primarily concerned that the surplus gain from curbing asset substitution may not offset the liquidation cost. Anticipating the regulator's heightened cost considerations, the bank has an incentive to originate riskier loans under expected loss in order to trim the liquidation value of the loans, thereby making liquidation even less appealing to the regulator.

Proposition 4 therefore delivers a message of caution about ELs. There is an endogenous cost of reporting nonincurred loan losses as it may result in changes in banks' lending behavior. Therefore, to assess the overall efficiency of the EL, the ex ante real effects must be weighed against the ex post benefits of timely intervention in curbing asset substitution. We next derive the conditions under which the ex post benefits exceed the ex ante costs triggered by the real effects and vice versa.

3.4 SURPLUS COMPARISON

To compare the results of endogenous loan risk choices with those of exogenous risk choices (Corollary 2), we first compare the surplus between the two provisioning models for a *given* capital ratio γ.

Proposition 5. *There exists a cutoff* $\gamma_W \in (\gamma_{\min}, \gamma_1)$ *such that*

1. *if the capital ratio is sufficiently low* ($\gamma \leq \gamma_{\min}$) *or the liquidation cost is sufficiently small* ($K \leq \underline{s}\alpha - \tau\beta$)*, the EL dominates the IL;*
2. *if the capital ratio is moderate* ($\gamma_W \leq \gamma < \gamma_1$) *and the liquidation cost is sufficiently large* ($K \geq \overline{K}$)*, the IL dominates the EL;*
3. *if the capital ratio is sufficiently high* ($\gamma \geq \gamma_1$)*, the bank surplus is identical under both loan loss provisioning models.*

Proposition 5 demonstrates that, with endogenous risk choices, the efficiency of the EL hinges on both the bank's capital structure and the effectiveness of regulatory intervention. The EL improves surplus when regulatory intervention is effective or the bank is insufficiently capitalized so that the menacing asset substitution risk provides strong justification for timely intervention; however, the EL becomes inferior when the bank is moderately capitalized and regulatory intervention is ineffective as it entails significant liquidation costs. Finally, when the bank is sufficiently capitalized, Corollary 1 suggests that the regulator never liquidates the bank so the bank surplus is identical under both provisioning models. Stated differently, Proposition 5 reinforces warnings that switching from an IL to an EL may not be a panacea: while it addresses risk-shifting concerns, it may still reduce financial stability—especially in economies where such risk-shifting problems are not too severe (e.g., banks are moderately capitalized) and regulatory intervention is not very effective.

The intuition for Proposition 5 is as follows. As explained previously, switching to the EL has both an ex ante effect and an ex post effect. The ex post effect always curbs risk-shifting and constitutes a benefit of the EL, whereas the sign of the ex ante effect is ambiguous. Therefore, a sufficient condition for the EL to dominate is that its ex ante effect is either neutral or positive in the sense that the early intervention under expected loss (weakly) disciplines ex ante risk-taking. From Proposition 4, this occurs when either the capital ratio is sufficiently low ($\gamma \leq \gamma_{\min}$) or the liquidation cost is small ($K \leq \underline{s}\alpha - \tau\beta$). More specifically, if the bank is highly leveraged ($\gamma \leq \gamma_{\min}$), the bank has an incentive to engage in asset substitution for any realization of its early signal s; in addition, anticipating that any loans originated will subsequently be either replaced by the high-risk asset under incurred loss, or liquidated under expected loss, the bank is deprived of any incentive to screen borrowers ($q^*_{EL} = q^*_{IL} = 0$). Accordingly, absent the ex ante effect, expected loss always dominates incurred loss due to its ex post benefit. Similarly, suppose that the liquidation cost is small ($K \leq \underline{s}\alpha - \tau\beta$). Proposition 4 implies that, in this scenario, implementing the EL always disciplines ex ante risk-taking. The timely intervention under expected loss then has dual benefits: it not only suppresses the bank's opportunity to switch its loans for the high-risk asset, but also induces the bank to originate higher quality loans in the first place. As a consequence, the EL will, again, dominate the IL. This explains part 1 of the proposition.

The IL can dominate the EL only when two requirements are met: (1) early intervention under expected loss aggravates ex ante risk-taking, and (2) the ex ante cost of such excessive risk-taking is sufficiently large and outweighs the ex post benefit. From Proposition 4, a sufficient condition for the first requirement is that the liquidation cost is sufficiently high ($K \geq \overline{K}$) so that regulatory intervention is likely to be ineffective. Assuming a large liquidation cost, we now explain why a sufficiently high capital ratio ($\gamma \geq \gamma_W$) causes the ex ante cost of expected loss to exceed its ex post benefit. The proof of Proposition 5 is instructive for conveying the key intuitions so we sketch it here. To begin, recall from Corollary 1, when the bank is sufficiently capitalized ($\gamma \geq \gamma_1$), the regulator will never intervene so that the bank surplus is identical under both provisioning models (part 3 of the proposition). Next, consider a value of γ just below γ_1, that is, $\gamma = \gamma_1 - \varepsilon$, where $\varepsilon > 0$ is an arbitrarily small positive number. A decrease of the capital ratio from γ_1 to $\gamma_1 - \varepsilon$ can potentially lead to a surplus difference between expected loss and incurred loss through two channels. First, under expected loss, shifting the capital ratio below γ_1 increases the equilibrium liquidation probability $P^*_L(\gamma)$ from zero to positive. At first glance, this may imply a surplus gain under expected loss because liquidation, in equilibrium, helps to curb inefficient asset substitution. However, recall that the regulator has already set the liquidation policy optimally to maximize the surplus; the envelope theorem then implies that at the optimal liquidation choice, a marginal increase in the liquidation probability $P^*_L(\gamma)$ will not affect the surplus, that is, $\frac{\partial W_{EL}}{\partial P_L}|_{P_L=P^*_L} = 0$. Intuitively, when the capital ratio drops just below the high level γ_1, the incremental ex post benefit of expected loss in curbing asset substitution is minimal because the tight ex ante capital requirements have already (almost) eliminated the bank's asset substitution incentive. Second, as the liquidation probability increases under expected loss, Proposition 4 suggests this also induces the bank to originate riskier loans ex ante in order to reduce the likelihood of liquidation upon regulatory intervention. This decrease in the loan quality, in turn, hurts the surplus under expected loss, that is, $\frac{\partial W_{EL}}{\partial q}|_{q=q^*_{EL}} > 0$.[12] In sum,

[12] Note that the envelope theorem cannot be applied to the marginal effect of changing the screening choice q on the surplus because the bank (the shareholders of the bank) chooses q to maximize its own payoff instead of the total surplus.

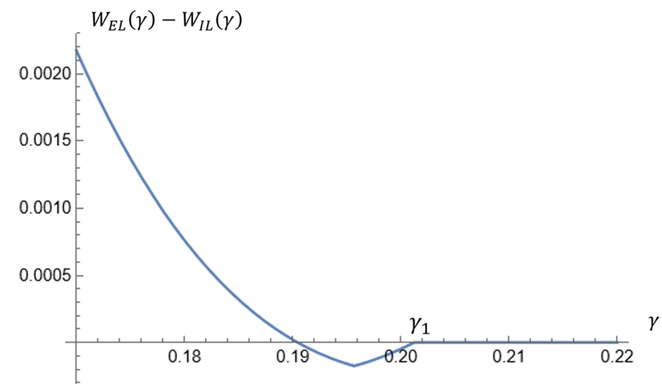

FIG 3.—Surplus difference between the expected loss and the incurred loss models with endogenous risk as a function of the capital ratio γ when the liquidity cost $K \geq \overline{K}$. The following parameter values are used in this plot: $\alpha = 1.1$, $\beta = 9/8$, $K = 0.058$, $\underline{s} = 0.9$, $\tau = 7/8$, and $C(q) = q^2/2$. Note that for $\gamma \geq \gamma_1 = 0.201$, $W_{EL} = W_{IL}$.

when the capital ratio is sufficiently high and close to γ_1, the ex ante cost of expected loss in inducing the bank to originate riskier loans dominates the ex post benefit. By continuity, the EL dominates the IL when the capital ratio is moderate ($\gamma_W \leq \gamma < \gamma_1$) and the liquidation cost is large. This explains part 2 of the proposition.

Finally, the fact that the EL improves the bank's surplus if the capital ratio is sufficiently low but reduces the surplus when the capital ratio is moderate suggests there exists a unique capital ratio threshold below which the EL dominates the IL. Although the complexity of our model prevents us from showing the existence of such a unique threshold, numerical simulations suggest that such a conjecture is indeed true, as illustrated in figure 3. Figure 3 shows that the surplus difference between the expected loss and the ILs becomes negative for moderate values of γ so that the IL indeed dominates the EL as shown in Proposition 5. But when the capital ratio is sufficiently large, the bank surplus is identical under the two provisioning models.

3.5 OPTIMAL CAPITAL REQUIREMENTS

An implication of Proposition 5 is that the economic consequences of implementing ELs are ambiguous and, importantly, depend on banks' capital ratios. A natural question then is if regulators adjusted capital ratios (via changing the regulatory treatment of accounting provisions), could they potentially eliminate the adverse effects of ELs? Put differently, does the adverse effect of ELs characterized in Proposition 5 arise only when the regulator does not tailor the capital ratio appropriately to the provisioning models? To shed some light on these questions, we next derive the optimal capital ratios under the two provisioning models and then compare the surpluses of the models at these optimal ratios.

3.5.1. Optimal Capital Ratios. Under incurred loss, the bank switches to the high-risk asset if $s < s_B$ so that the expected surplus is $\tau\beta$, whereas the bank keeps its loan if $s \geq s_B$ and the expected surplus is $[s + (1-s)q^*_{IL}]\alpha$. We can therefore write the surplus under incurred loss as

$$W_{IL}(\gamma) = A \times NPV_{IL}(\gamma), \tag{19}$$

where

$$NPV_{IL}(\gamma) = \int_{\underline{s}}^{s_B} \tau\beta h(s)\,ds + \int_{s_B}^{1} \left[s + (1-s)q^*_{IL}\right]\alpha h(s)\,ds - 1, \tag{20}$$

measures the per-unit NPV from the bank's assets under incurred loss. Taking the first-order condition yields

$$\frac{dW_{IL}}{d\gamma} = \frac{\partial A}{\partial \gamma} NPV_{IL}(\gamma) + A\frac{\partial NPV_{IL}}{\partial s_B}\frac{ds_B}{d\gamma} + A\frac{\partial NPV_{IL}}{\partial q}\frac{\partial q^*_{IL}}{\partial \gamma}. \tag{21}$$

The first term in $\frac{dW_{IL}}{d\gamma}$ represents the potential social cost of increasing the capital ratio. Intuitively, increasing the capital ratio restrains bank lending ($\frac{\partial A}{\partial \gamma} < 0$), which reduces the surplus if the per-unit NPV from bank's assets is positive ($NPV_{IL} > 0$). It is straightforward to verify that the NPV is positive if and only if the capital ratio γ is sufficiently large. The reason is that, if the bank is sufficiently capitalized, it has strong incentives to exert screening effort to originate high-quality loans (high q^*_{IL}) and weak incentives to replace the loans with the high-risk asset (low s_B), both of which improve the NPV of the bank.

The other two terms in $\frac{dW_{IL}}{d\gamma}$ are both positive and represent the social benefits of increasing the capital ratio. In particular, the second term captures the effect of increasing the capital ratio in disciplining the bank's asset substitution incentive ex post ($\frac{ds_B}{d\gamma} < 0$), whereas the third term captures the social benefit of increasing the capital ratio in motivating the bank to exert screening effort ex ante ($\frac{\partial q^*_{IL}}{\partial \gamma} > 0$).[13] The regulator sets the optimal capital requirements ratio by trading off the benefits against the costs. We denote the optimal capital ratio under the IL by γ^*_{IL} which solves the first-order condition (21).

Note that the regulator's early intervention under expected loss leads to two differences between the NPV of the bank's assets compared to the IL. First, under expected loss, the bank switches to the high-risk asset if the regulator chooses not to liquidate upon intervention, that is, $s < s_L$, whereas under incurred loss, the bank switches if $s < s_B$. Second, in the

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[13] Mathematically, the second term in $\frac{dW_{IL}}{d\gamma}$ is positive because (1) $\frac{\partial NPV_{IL}}{\partial s_B} < 0$ as by Assumption 4, asset substitution is value-destroying and (2) $\frac{ds_B}{d\gamma} = \frac{\partial s_B}{\partial \gamma} + \frac{\partial s_B}{\partial q}\frac{\partial q^*_{IL}}{\partial \gamma}$. From Proposition 1, $\frac{\partial s_B}{\partial \gamma} < 0$ and $\frac{\partial s_B}{\partial q} < 0$. In addition, from Proposition 3, $\frac{\partial q^*_{IL}}{\partial \gamma} > 0$. Hence, $\frac{ds_B}{d\gamma} < 0$. The third term is positive because (1) from Proposition 3, $\frac{\partial q^*_{IL}}{\partial \gamma} > 0$ and (2) higher quality loans yield higher returns $\frac{\partial NPV_{IL}}{\partial q} > 0$.

liquidation region of $s \in (s_L, s_B)$, the regulator incurs the liquidation cost K. The surplus under expected loss is therefore given by

$$W_{EL}(\gamma) = A \times NPV_{EL}(\gamma), \tag{22}$$

where

$$NPV_{EL}(\gamma) = \int_{\underline{s}}^{s_L} \tau\beta h(s)\,ds + \int_{s_L}^{1} \left[s + (1-s)\,q_{EL}^*\right]\alpha h(s)\,ds - 1 - \int_{s_L}^{s_B} Kh(s)\,ds, \tag{23}$$

measures the per-unit NPV from the bank's assets under expected loss. To derive the optimal capital ratio under the EL, we take the first-order condition of $W_{EL}(\gamma)$ with respect to γ to get

$$\frac{dW_{EL}}{d\gamma} = \frac{\partial A}{\partial \gamma} NPV_{EL}(\gamma) + A\frac{\partial NPV_{EL}}{\partial s_B}\frac{ds_B}{d\gamma} + A\frac{\partial NPV_{EL}}{\partial q}\frac{\partial q_{EL}^*}{\partial \gamma}. \tag{24}$$

The first-order condition (24) is analogous to (21) under incurred loss. Note that as explained previously, although a change in the capital ratio affects the regulator's liquidation decision (in particular, the liquidation threshold s_L or the equilibrium liquidation probability $P_L^*(\gamma)$), this change of the liquidation decision has no marginal effect on the surplus by the envelope theorem. We denote the optimal capital ratio under the EL by γ_{EL}^*. For future references, we formally state the equilibrium of the optimal capital ratios in the following proposition.

Proposition 6. *Under the IL, the regulator chooses the capital ratio γ_{IL}^* that solves equation (21). Under the EL, the regulator chooses the capital ratio γ_{EL}^* that solves equation (24).*

3.5.2. Surplus Comparison Under Optimal Capital Ratios. We now compare the surplus between the provisioning models evaluated at the optimal capital ratios, that is, $W_{IL}(\gamma_{IL}^*)$ and $W_{EL}(\gamma_{EL}^*)$. Because γ_{IL}^* and γ_{EL}^* are defined by implicit solutions to differential equations, in general, we are unable to compare $W_{IL}(\gamma_{IL}^*)$ and $W_{EL}(\gamma_{EL}^*)$ analytically. For the rest of the analysis, we first derive some analytical results when the liquidation cost K is small ($K \leq \underline{s}\alpha - \tau\beta$) and then supplement them with numerical simulations that consider a wide range of values for K.

When the liquidation cost is small ($K \leq \underline{s}\alpha - \tau\beta$), Proposition 5 states that the EL dominates the IL for all ranges of capital ratios γ, and thus it should also dominate when the regulator sets the capital requirements policy optimally. Formally, we state this result in the following corollary.

Corollary 3. *If the liquidation cost $K \leq \underline{s}\alpha - \tau\beta$ so that regulatory intervention is highly effective, the EL dominates the IL under the optimal capital ratios.*

Although Corollary 3 establishes the optimality of the EL conditional on a low liquidation cost, it provides no insight into how the regulator should adjust the capital ratios when the EL is introduced. Nonetheless, answering this question is important as it can generate implications for the optimal design of capital requirements under ELs such as CECL. Toward this end, we now provide some analysis of the optimal capital ratios under the two provisioning models when the liquidation cost is low ($K \leq \underline{s}\alpha - \tau\beta$). To start, recall from Corollary 1, a higher capital ratio allows the regulator to liquidate less frequently upon intervention. Therefore, one may conjecture that the converse is also true, that is, the option of interim liquidation under expected loss allows the regulator to relax the capital requirements. Due to the lack of closed-form solutions to γ_{IL}^* and γ_{EL}^*, we cannot compare them directly to verify the conjecture. To facilitate this comparison, we hereafter impose two additional assumptions for the rest of the analysis.

Assumption 8. *The surplus functions W_{IL} and W_{EL} are both single-peaked in $\gamma \in [\underline{\gamma}, 1]$, that is, there exists a unique γ_i^*, where $i \in \{IL, EL\}$, such that $\frac{\partial W_i}{\partial \gamma} > 0$ if and only if $\gamma < \gamma_i^*$.*

The assumption guarantees the uniqueness of the optimal capital ratios and rules out scenarios in which there are multiple spikes in the surplus functions. Numerical examples suggest that the surplus functions are indeed single-peaked.

Assumption 9. *Absent asset substitution, the bank's assets, ex ante, generate a positive NPV, that is, $NPV_i \geq 0$, where $i \in \{IL, EL\}$.*

The assumption rules out uninteresting scenarios in which the cost of screening $C(q)$ is so steep that the bank has no incentive to screen borrowers and originate loans with positive NPVs.

Given these two assumptions, we next derive a sufficient condition under which $\gamma_{EL}^* < \gamma_{IL}^*$, that is, the regulator should lower the capital requirements in response to the implementation of the EL.

Proposition 7. *Suppose the liquidation cost $K \leq \underline{s}\alpha - \tau\beta$. There exists thresholds $\bar{s}$ and $\underline{h}$, such that, if $\Pr(s < \bar{s}) > \underline{h}$, that is, the probability that the loan yields a low performance is sufficiently large, the regulator sets tighter capital requirements under the IL than under the EL, that is, $\gamma_{EL}^* < \gamma_{IL}^*$.*

Proposition 7 identifies a region of parameters in which the regulator may be able to relax the capital requirements when banks use the EL for loan loss provisioning. In that region, the likelihood of the bad interim information is relatively high, and regulatory intervention is relatively frictionless and entails a small liquidation cost. The intuition behind Proposition 7 is twofold. First, recall that when the liquidation cost is sufficiently small, the bank always exerts more screening effort under the EL. This implies that under expected loss, the regulator faces a smaller pressure to raise the capital ratio in order to discipline the bank's ex ante risk-taking incentive. Second, note that the likelihood of asset substitution is greater if the interim signal is more likely to be bad. Under the incurred loss model, the regulator must tighten the capital requirements constraint to counter the bank's menacing asset substitution incentive. But under the EL, the regulator has an additional lever, that is, interim liquidation. As the bank's asset substitution incentive is partially mitigated by the interim

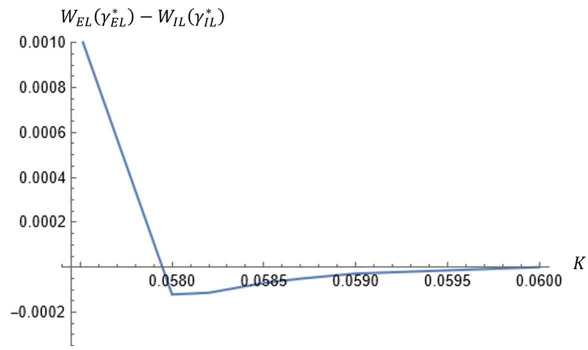

FIG 4.—Surplus difference between the expected loss and the incurred loss models with endogenous risk and optimal capital ratios for a given liquidation cost K. The following parameter values are used in this plot: $\alpha = 1.1$, $\beta = 9/8$, $\underline{s} = 0.9$, $\tau = 7/8$, and $C(q) = q^2/2$.

liquidation, ex ante the regulator can actually relax the capital requirements constraint to spur credit supply, yet without triggering excessive risk-taking, under the EL.

When the liquidation cost is sufficiently large, however, Proposition 5 suggests that there are both a benefit and a cost of implementing an EL for a given capital ratio. One may wonder whether the trade-off between the two provisioning models extends to the case when the regulator sets the capital ratios optimally. As the analysis of the case with a high liquidation cost is largely intractable, we turn to numerical simulations. Figure 4 provides a graphical illustration of how the size of the liquidation cost affects the surplus difference between the provisioning models under the optimal capital requirements. The figure suggests that, when the regulator sets the capital ratios optimally, the economic consequence of introducing an EL remains ambiguous. Indeed, the results from our numerical simulations are in line with the message in Proposition 5. The EL improves surplus when intervening in banks' operations is relatively frictionless (low K). However, when the liquidation cost rises above a threshold, the EL becomes inferior due to its ex ante risk aggravating effect.[14] We state this observation below.

Observation 1 *When the liquidation cost K is sufficiently large, the IL can dominate the EL even under the optimal capital ratios.*

From a policy perspective, observation 1 implies that implementing an EL such as CECL would contribute to financial instability in the banking sector (via prompting excessive risk-taking) and have the most damaging economic impact when regulatory intervention is likely to be ineffective. Furthermore, such adverse real effect cannot be overturned even if regulators have the full flexibility of tailoring the capital ratio to the provisioning

[14] Note that, in figure 4, when the liquidation cost is excessively large, the surpluses under the two provisioning models are identical because the regulator ceases to intervene under the EL.

model. As a consequence, in economies that fall under this category, the most effective policy prescription for maintaining financial stability would be for not incorporating expected-loss information in the calculation of regulatory capital. From an empirical perspective, our model potentially helps reconcile the cross-country variations in the way regulators adjusted capital requirements when ELs were introduced.

Another implication of observation 1 is that in countries that have already adopted ELs, it would be desirable for regulators to commit ex ante not to intervene in situations where the IL dominates (i.e., when the liquidation cost K is large). One potential way to build such commitments is to, ex ante, adopt a variant of the EL with a prudential filter such that changes in credit risk do not affect regulatory capital. Such a modified EL would then be equivalent to the IL, and, from observation 1, superior to the unmodified EL when the liquidation cost is large.[15]

4. *Conclusion and Discussion*

It is generally believed that a lesson from the 2007–2009 global financial crisis was that ILs often resulted in provisions that were "too little, too late." Therefore, timely loan loss provisioning—via ELs such as CECL and IFRS 9—would promote safe and sound banking systems by playing an important role in bank regulation and supervision. One important insight of our study is that—as long as regulatory intervention is effective—timely loan loss provisioning can indeed improve financial stability—especially when banks are poorly capitalized and therefore have sharp incentives to engage in excessive risk-shifting. However, our study also provides a cautionary message: while timely loan loss provisioning addresses risk-shifting concerns, it may still reduce financial stability—especially in economies where such risk-shifting problems are not too severe (e.g., banks are moderately capitalized) and regulatory intervention is not very effective. Another important and related insight is on the regulatory treatment of accounting provisions. We show that regulators may spur credit supply by tailoring regulatory capital to information about loan losses. More precisely, relative to ILs, optimal regulatory capital under ELs may be looser when regulatory intervention is relatively frictionless and the likelihood of recognizing large expected loan losses is high. However, in environments in which regulatory intervention is plagued with frictions and likely to be ineffective, early recognition of expected loan losses can distort banks' incentives to screen borrowers, thereby hampering efficient bank credit supply and diminishing the surplus that banks create. Such surplus loss persists even if bank regulators tailor the regulatory capital ratio to the provisioning models.

Our model may be used as a springboard to study other important aspects of loan loss provisioning that we do not capture in our environment.

[15] We thank the Associate Editor for bringing up the interesting point of whether the regulator could design prudential filters to serve as ex ante commitment devices.

Banks are often criticized for exercising a large amount of discretion in estimating and disclosing their loan losses, even under the IL. Arguably, such discretion will only increase when it comes to estimating expected loan losses. To the extent that banks' discretionary reporting of loan loss provisions hides loan loss information from regulators, it may result in an additional cost of ELs that we have ignored in our analysis. How such a cost of reporting discretion may be traded against the cost and the benefit identified in our model is an interesting avenue for future research. We have also not considered how loan loss provisioning may lead to spillovers and affect the systemic risk of the banking industry (e.g., procyclicality of bank lending). In the current debate, there are concerns that the IL may have contributed to procyclicality and adopting the new EL may help to mitigate procyclicality.[16] Extending our single-bank model to include multiple banks may thus shed light on the systemic impact of loan loss provisioning, which is another interesting avenue for future research.

REFERENCES

Abad, J., and J. Suarez. "The Procyclicality of Expected Credit Loss Provisions." (2018). CEPR Discussion Paper No. DP13135, Available at SSRN: https://ssrn.com/abstract=3244507

Acharya, V. V., and S. G. Ryan. "Banks' Financial Reporting and Financial System Stability." *Journal of Accounting Research* 54 (2016): 277–340.

Agenor, P.-R., and R. Zilberman. "Loan Loss Provisioning Rules, Procyclicality, and Financial Volatility." *Journal of Banking and Finance* 61 (2015): 301–15.

Allen, F., and E. Carletti. "Mark-to-Market Accounting and Liquidity Pricing." *Journal of Accounting and Economics* 45 (2008): 358–78.

Akins, B., Y. Dou, and J. Ng. "Corruption in Bank Lending: The Role of Timely Loan Loss Recognition." *Journal of Accounting and Economics* 63 (2017): 454–78.

Bagehot, W. *Lombard Street: A Description of the Money Market*. London: HS King, 1873.

Basel Committee. "Basel III: A Global Regulatory Framework for More Resilient Banks and Banking Systems." Basel Committee on Banking Supervision, Basel, 2010.

Basel Committee on Banking Supervision. "The Procyclicality of Loan Loss Provisions: A Literature Review." Basel Committee on Banking Supervision Working Paper 39, 2021.

Beatty, A., and S. Liao. "Do Delays in Expected Loss Recognition Affect Banks' Willingness to Lend?" *Journal of Accounting and Economics* 52 (2011): 1–20.

Beatty, A., and S. Liao. "Financial Accounting in the Banking Industry: A Review of the Empirical Literature." *Journal of Accounting and Economics* 58 (2014): 339–83.

Bennett, R. L., and H. Unal. "Understanding the Components of Bank Failure Resolution Costs." *Financial Markets, Institutions & Instruments* 24 (2015): 349–89.

Bertomeu, J., L. Mahieux, and H. Sapra. "Interplay between Accounting and Prudential Regulation." *The Accounting Review* (2022). https://doi.org/10.2308/TAR-2018-0705

Bischof, J., C. Laux, and C. Leuz. "Accounting for Financial Stability: Bank Disclosure and Loss Recognition in the Financial Crisis." *Journal of Financial Economics* 141 (2021): 1188–217.

Bonfim, D., G. Cerqueiro, H. Degryse, and S. Ongena. "On-Site Inspecting Zombie Lending." Swiss Finance Institute Research Paper 20-16, 2020.

[16] For theoretical and empirical work on provisioning and procyclicality, see Abad and Suarez [2018], Agenor and Zilberman [2015], Beatty and Liao [2014], Bouvatier and Lepetit [2012], Dewatripont and Tirole [2012], and Goncharenko and Rauf [2019].

Bouvatier, V., and L. Lepetit. "Provisioning Rules and Bank Lending: A Theoretical Model." *Journal of Financial Stability* 8 (2012): 25–31.

Burkhardt, K., and R. Strausz. "Accounting Transparency and the Asset Substitution Problem." *The Accounting Review* 84 (2009): 689–712.

Bushman, R. M., and C. D. Williams. "Accounting Discretion, Loan Loss Provisioning, and Discipline of Banks' Risk-Taking." *Journal of Accounting and Economics* 54 (2012): 1–18.

Bushman, R. M., and C. D. Williams. "Delayed Expected Loss Recognition and the Risk Profile of Banks." *Journal of Accounting Research* 53 (2015): 511–53.

Corona, C., L. Nan, and G. Zhang. "Accounting Information Quality, Interbank Competition, and Bank Risk Taking." *The Accounting Review* 90 (2015): 967–85.

Corona, C., L. Nan, and G. Zhang. "Banks' Asset Reporting Frequency and Capital Regulation: An Analysis of Discretionary use of Fair-Value accounting." *The Accounting Review* 94 (2019): 157–78.

Corona, C., L. Nan, and G. Zhang. "The Coordination Role of Stress Tests in Bank Risk Taking." *Journal of Accounting Research* 57 (2019): 1161–200.

Dewatripont, M., and J. Tirole. The Prudential Regulation of Banks, Vol. 1. Cambridge, MA: MIT Press, 1994a.

Dewatripont, M., and J. Tirole. "A Theory of Debt and Equity: Diversity of Securities and Manager-Shareholder Congruence." *The Quarterly Journal of Economics* 109 (1994b): 1027–54.

Dewatripont, M., and J. Tirole. "Macroeconomic Shocks and Bank Regulation." *Journal of Money, Credit and Banking* 44 (2012): 237–54.

Financial Accounting Standards Board. Accounting Standards Update No. 2016-13. Financial Instruments-Credit Losses (Topic 326), 2016.

Financial Accounting Standards Board. "Public Round Table Meeting on Credit Losses." 2019. Available at https://www.youtube.com/watch?v=FH7xWZsCX9s&t=2866s.

FDIC Law. "Regulations, Related Acts." 2021. Available at https://www.fdic.gov/regulations/laws/rules.

Freixas, X. "Optimal Bail Out Policy, Conditionality and Constructive Ambiguity." (1999). Working Paper No. 400, Available at SSRN: https://ssrn.com/abstract=199054 or https://doi.org/10.2139/ssrn.199054

Gao, P., and X. Jiang. "Reporting Choices in the Shadow of Bank Runs." *Journal of Accounting and Economics* 65 (2018): 85–108.

Goldstein, I., and H. Sapra. "Should Banks' Stress Test Results be Disclosed? An Analysis of the Costs and Benefits." *Foundations and Trends in Finance* 8 (2014): 1–54.

Goncharenko, R., and A. Rauf. "Loan Loss Provisioning Requirements in a Dynamic Model of Banking." 2019. Available at SSRN 3247631.

Heaton, J. C., D. Lucas, and R. L. McDonald. "Is Mark-To-Market Accounting Destabilizing? Analysis and Implications for Policy." *Journal of Monetary Economics* 57 (2010): 64–75.

Laux, C., and T. Rauter. "Procyclicality of US Bank Leverage." *Journal of Accounting Research* 55 (2017): 237–73.

Liang, P. J., and G. Zhang. "On the Social Value of Accounting Objectivity in Financial Stability." *The Accounting Review* 94 (2019): 229–48.

Lopez-Espinosa, G., G. Ormazabal, and Y. Sakasai. "Switching from Incurred to Expected Loan Loss Provisioning: Early Evidence." *Journal of Accounting Research* 59 (2021): 757–804.

Lu, Y., and V. V. Nikolaev. "Expected Loan Loss Provisioning: An Empirical Model." *The Accounting Review* (2022). https://doi.org/10.2308/TAR-2019-0128

Lu, T., H. Sapra, and A. Subramanian. "Agency Conflicts, Bank Capital Regulation, and Marking-to-Market." *The Accounting Review* 94 (2019): 365–84.

Mahieux, L. "Fair Value Accounting, Illiquid Assets, and Financial Stability." Working paper, 2021.

Mailath, G. J., and L. J. Mester. "A Positive Analysis of Bank Closure." *Journal of Financial Intermediation* 3 (1994): 272–99.

Maurer, M. "Lawmakers Press Rule Maker on Economic Impact of Credit Loss Standard." *The Wall Street Journal*, 2020. Available at https://www.wsj.com/articles/lawmakers-press-rule-maker-on-economic-impact-of-credit-loss-standard-11579139500.

Passalacqua, A., P. Angelini, F. Lotti, and G. Soggia. "The Real Effects of Bank Supervision: Evidence from On-Site Bank Inspections." Bank of Italy Temi di Discussione (Working Paper) No. 1349, 2021.

Plantin, G., H. Sapra, and H. S. Shin. "Marking-to-Market: Panacea or Pandora's Box?" *Journal of Accounting Research* 46 (2008): 435–60.

Quaadman, T. "U.S. Chamber of Commerce's Comment Letter to the SEC and FASB." 2019. Available at https://www.centerforcapitalmarkets.com/wp-content/uploads/2019/01/Chamber-CECL-Letter.pdf?#.

Zhang, G. "Competition and Opacity in the Financial System." *Management Science* 67 (2021): 1895–913.

APPENDIX APROOFS

A.1 PROOF OF PROPOSITION 1

At $t = 1$, the bank asset substitutes if and only if

$$\tau\big[\beta - (1-\gamma)\big] > \big[s + (1-s)q\big]\big[\alpha - (1-\gamma)\big]. \tag{A.1}$$

This, in turn, implies that the bank asset substitutes if and only if $s < s_B$, where

$$s_B = \frac{\tau}{1-q}\frac{\beta - (1-\gamma)}{\alpha - (1-\gamma)} - \frac{q}{1-q}. \tag{A.2}$$

The condition $s_B < 1$ is equivalent to

$$\gamma > \gamma_{\min} = \frac{\tau(\beta - 1) - (\alpha - 1)}{1-\tau}.$$

Similarly, the condition $s_B > \underline{s}$ is equivalent to

$$\gamma < \gamma_{\max}(q) = \frac{\tau(\beta-1) - \big[q + (1-q)\underline{s}\big](\alpha - 1)}{q + (1-q)\underline{s} - \tau}. \tag{A.3}$$

Moreover, Assumption 6 implies that the condition in (A.1) is always satisfied at $\gamma = \underline{\gamma}$. At $\gamma = 1$, Assumption 4 implies that the condition in (A.1) is not satisfied because $\underline{s}\alpha > \tau\beta$. Thus, we have $\underline{\gamma} < \gamma_{\min} < \gamma_{\max}(q) < 1$.

Finally, taking the derivative of (A.2) yields:

$$\frac{\partial s_B}{\partial q} = \frac{\big(\tau\big[\beta - (1-\gamma)\big] - \big[\alpha - (1-\gamma)\big]\big)\big[\alpha - (1-\gamma)\big]}{(1-q)^2\big[\alpha - (1-\gamma)\big]} \leq 0.$$

In addition,

$$\frac{\partial s_B}{\partial \gamma} = \frac{-\tau(\beta - \alpha)}{(1-q)\big[\alpha - (1-\gamma)\big]^2} \leq 0.$$

The inequalities are strict if $\gamma \in (\gamma_{\min}, \gamma_{\max})$.

A.2 PROOF OF LEMMA 1

See the main text.

A.3 PROOF OF PROPOSITION 2

From the main text, (12) implies that, anticipating that the bank will asset-substitute, that is, $s < s_B$, the regulator liquidates the bank if and only if $s \in (s_L, s_B)$, where

$$s_L = \frac{1}{1-q}\frac{\tau\beta + K}{\alpha} - \frac{q}{1-q}. \quad \text{(A.4)}$$

The condition $s_L < 1$ is equivalent to $\tau\beta + K < \alpha$, which is always satisfied by Assumption 5. Similarly, the condition $s_L > \underline{s}$ is equivalent to

$$q < \frac{K - (\underline{s}\alpha - \tau\beta)}{\alpha(1-\underline{s})}.$$

In sum, when $q < \frac{K-(\underline{s}\alpha-\tau\beta)}{\alpha(1-\underline{s})}$, the regulator liquidates if and only if $s \in (s_L, s_B)$. When $q \geq \frac{K-(\underline{s}\alpha-\tau\beta)}{\alpha(1-\underline{s})}$, $s_L \leq \underline{s}$, and the regulator liquidates if and only if $s < s_B$.

Taking the derivative (A.4) with respect to q gives that

$$\frac{\partial s_L}{\partial q} = \frac{(\tau\beta + K - \alpha)\alpha}{(1-q)^2\alpha} < 0.$$

A.4 PROOF OF COROLLARY 1

If $q < \frac{K-(\underline{s}\alpha-\tau\beta)}{\alpha(1-\underline{s})}$, the set of s in which the regulator liquidates the bank, that is, $s \in (s_L, s_B)$, is nonempty if and only if $s_B > s_L$. Note that

$$\begin{aligned} s_B - s_L &= \frac{\tau}{1-q}\frac{\beta-(1-\gamma)}{\alpha-(1-\gamma)} - \frac{q}{1-q} - \frac{1}{1-q}\frac{\tau\beta+K}{\alpha} + \frac{q}{1-q} \\ &= \frac{1}{1-q}\frac{\tau(\beta-\alpha)(1-\gamma) - K\big[\alpha-(1-\gamma)\big]}{\alpha\big[\alpha-(1-\gamma)\big]}. \quad \text{(A.5)} \end{aligned}$$

Thus, $s_B - s_L > 0$ is equivalent to

$$\gamma < \frac{\tau(\beta-\alpha) - K(\alpha-1)}{\tau(\beta-\alpha)+K} \equiv \gamma_1 < 1. \quad \text{(A.6)}$$

The last inequality uses $\beta > \alpha > 1$. Therefore, if $\gamma \geq \gamma_1$, $s_B \leq s_L$ such that the regulator never liquidates the bank. One can verify that $\gamma_1 > \gamma_{\min}$ is equivalent to $K < \alpha - \tau\beta$, which is always satisfied by Assumption 5.

If $q \geq \frac{K-(\underline{s}\alpha-\tau\beta)}{\alpha(1-\underline{s})}$,

$$s_L = \frac{1}{1-q}\frac{\tau\beta+K}{\alpha} - \frac{q}{1-q} \leq \underline{s}.$$

In addition, if $\gamma \geq \gamma_1$, from (A.5), $s_B \leq s_L = \underline{s}$ such that the bank never engages in asset substitution and the regulator never liquidates the bank.

A.5 PROOF OF COROLLARY 2

The surplus under incurred loss is

$$W_{IL}(\gamma) = \frac{E}{\gamma}\left(\int_{\underline{s}}^{s_B} \tau\beta h(s)\,ds + \int_{s_B}^{1} \left[s + (1-s)q\right]\alpha h(s)\,ds - 1\right). \quad (A.7)$$

The bank keeps the original loan if $s \geq s_B$ and switches to a high-risk asset if $s < s_B$.

Under the EL, the surplus is

$$W_{EL}(\gamma) = \frac{E}{\gamma}\left(\int_{\underline{s}}^{s_L} \tau\beta h(s)\,ds + \int_{s_L}^{1} \left[s + (1-s)q\right]\alpha h(s)\,ds - \int_{s_L}^{s_B} Kh(s)\,ds - 1\right). \quad (A.8)$$

The only difference between the incurred and the ELs is that, if $s_L < s < s_B$, the bank is liquidated under the EL, whereas the bank is allowed to continue and asset-substitute under the IL. Recognizing this difference, we obtain:

$$W_{EL}(\gamma) - W_{IL}(\gamma) = \frac{E}{\gamma}\left[\int_{s_L}^{s_B} \left\{\left[(s + (1-s)q\right]\alpha - \tau\beta - K\right\}h(s)\,ds\right] \geq 0. \quad (A.9)$$

The last inequality uses the definition of s_L from (12).

A.6 PROOF OF PROPOSITION 3

For our convenience, we first reproduce the first-order condition regarding q^*_{IL} below:

$$\int_{s_B}^{1} (1-s)\left[\alpha - (1-\gamma)\right]h(s)\,ds = C'\left(q^*_{IL}\right). \quad (A.10)$$

Consider first the case that $s_B = 1$, which, from Proposition 1, holds when $\gamma \in [\underline{\gamma}, \gamma_{\min}]$. Plugging $s_B = 1$ into (A.10) shows that the left-hand side of (A.10) equals 0. Therefore, $q^*_{IL} = 0$.

Second, suppose that $s_B \in (\underline{s}, 1)$, which, from Proposition 1, holds when $\gamma \in (\gamma_{\min}, \gamma_{\max}(q))$. In the case, q^*_{IL} is the interior solution that solves (A.10). Given $q = q^*_{IL}$, the condition that $\gamma < \gamma_{\max}(q)$ reduces into $\gamma < \gamma_2$, where the cutoff γ_2 solves $\gamma_2 = \gamma_{\max}(q^*_{IL}(\gamma_2))$. Therefore, if $\gamma \in (\gamma_{\min}, \gamma_2)$, then q^*_{IL} is given by (A.10).

Finally, suppose that $s_B = \underline{s}$, which, from Proposition 1, holds when $\gamma \in [\gamma_{\max}(q), 1]$. Plugging $s_B = \underline{s}$ into (A.10) gives that

$$\int_{\underline{s}}^{1} (1-s)\left[\alpha - (1-\gamma)\right]h(s)\,ds = C'\left(q^*_{IL}\right). \quad (A.11)$$

Given $q = q^*_{IL}$, the condition that $\gamma \geq \gamma_{\max}(q)$ reduces into $\gamma \geq \gamma_2$, where the cutoff γ_2 solves $\gamma_2 = \gamma_{\max}(q^*_{IL}(\gamma_2))$. Therefore, if $\gamma \in [\gamma_2, 1]$, then q^*_{IL} is given by (A.11).

Finally, we prove that q^*_{IL} increases in γ. When $\gamma \in [\gamma_2, 1]$, as the left-hand side of (A.11) is strictly increasing in γ, an application of the implicit function theorem proves that q^*_{IL} increases in γ. Next, suppose that

$\gamma \in (\gamma_{\min}, \gamma_2)$. Applying the implicit function theorem to equation (A.10) yields:

$$C''\left(q_{IL}^*\right)\frac{\partial q_{IL}^*}{\partial \gamma} = \int_{s_B}^{1} (1-s)h(s)\,ds - \left(\frac{\partial s_B}{\partial \gamma} + \frac{\partial q_{IL}^*}{\partial \gamma}\frac{\partial s_B}{\partial q}\right)(1-s_B)\big[\alpha - (1-\gamma)\big]h(s_B).$$

Applying the definition of s_B in Proposition 1 yields:

$$\frac{\partial s_B}{\partial \gamma} + \frac{\partial q_{IL}^*}{\partial \gamma}\frac{\partial s_B}{\partial q} = -\frac{1}{1-q_{IL}^*}\frac{\tau(\beta-\alpha)}{(\alpha-(1-\gamma))^2} + \frac{1}{(1-q_{IL}^*)^2}\left(\frac{\tau(\beta-\alpha)}{\alpha-(1-\gamma)} - 1\right)\frac{\partial q_{IL}^*}{\partial \gamma}.$$

This can be simplified into:

$$\frac{\partial q_{IL}^*}{\partial \gamma} = \frac{\int_{s_B}^{1}(1-s)h(s)\,ds + \frac{1}{1-q_{IL}^*}\frac{(1-s_B)\tau(\beta-\alpha)}{\left[\alpha-(1-\gamma)\right]}h(s_B)}{C''\left(q_{IL}^*\right) + \frac{1}{(1-q_{IL}^*)^2}(1-s_B)\left(\tau(\beta-\alpha) - \alpha + (1-\gamma)\right)h(s_B)}.$$

The denominator is positive by the second-order condition of q_{IL}^*, whereas the numerator is strictly positive. In sum, q_{IL}^* is increasing in γ from 0 at $\gamma = \gamma_{\min}$ to $q_{IL}^*(1)$ at $\gamma = 1$, where $q_{IL}^*(1)$ solves $C'(q_{IL}^*(1)) = \int_{\underline{s}}^{1}(1-s)\alpha h(s)\,ds$.

A.7 PROOF OF PROPOSITION 4

For our convenience, we first reproduce the first-order condition regarding q_{EL}^* below:

$$C'\left(q_{EL}^*\right) = \tau\big[\beta - (1-\gamma)\big]\left[\frac{\partial s_L}{\partial q}h(s_L) - \frac{\partial s_B}{\partial q}h(s_B)\right] + \int_{s_B}^{1}(1-s)\big[\alpha - (1-\gamma)\big]h(s)\,ds.$$

Under the uniform distribution assumption $h(s) = \frac{1}{1-\underline{s}}$, the first-order condition is reduced into:

$$C'\left(q_{EL}^*\right) = \frac{\tau\big[\beta-(1-\gamma)\big]}{1-\underline{s}}\left(\frac{\partial s_L}{\partial q} - \frac{\partial s_B}{\partial q}\right) + \frac{\alpha-(1-\gamma)}{1-\underline{s}}\int_{s_B}^{1}(1-s)\,ds. \quad \text{(A.12)}$$

To solve the first-order condition, suppose first that $\gamma \in [\gamma_{\max}(q), 1]$ such that $s_B = \underline{s}$. Hence, the bank will never asset-substitute and the regulator will never intervene. The first-order condition (A.12) reduces into:

$$C'\left(q_{EL}^*\right) = \frac{\alpha-(1-\gamma)}{1-\underline{s}}\int_{\underline{s}}^{1}(1-s)\,ds.$$

Note that $q_{EL}^* = q_{IL}^*$. Hence, the condition that $\gamma \geq \gamma_{\max}(q)$ reduces into $\gamma \geq \gamma_2$, where the cutoff γ_2 solves $\gamma_2 = \gamma_{\max}(q_{IL}^*(\gamma_2))$ and q_{IL}^* is defined in Proposition 3.

For $\gamma < \gamma_2$, we consider two cases: (1) $q_{EL}^* < \frac{K-(\underline{s}\alpha-\tau\beta)}{\alpha(1-\underline{s})}$ such that, from Proposition 2, the regulator intervenes if and only if $s \in (s_L, s_B)$; and (2) $q_{EL}^* \geq \frac{K-(\underline{s}\alpha-\tau\beta)}{\alpha(1-\underline{s})}$ such that the regulator intervenes if and only if $s < s_B$. We will reduce the condition of $q_{EL}^* < \frac{K-(\underline{s}\alpha-\tau\beta)}{\alpha(1-\underline{s})}$ into a restriction on exogenous parameters after we solve the equilibrium.

Case 1: $q^*_{EL} < \frac{K-(\underline{s}\alpha-\tau\beta)}{\alpha(1-\underline{s})}$. Suppose first that $\gamma < \gamma_2$ such that $s_B > \underline{s}$. If $\gamma \in [\gamma_1, \gamma_2)$[17], by Proposition 2, the regulator never intervenes and the first order condition (A.12) reduces into:

$$C'\left(q^*_{EL}\right) = \frac{\alpha - (1-\gamma)}{1-\underline{s}} \int_{s_B}^{1} (1-s)\,ds. \tag{A.13}$$

Note that, again, $q^*_{EL} = q^*_{IL}$. Next suppose that $\gamma < \gamma_1$ such that $s_B > s_L > \underline{s}$. Note that at $\gamma = \gamma_{\min}$, the right-hand side of (A.12) is strictly negative because $s_B = 1$ (Proposition 1), that is,

$$\frac{\tau\left[\beta - (1-\gamma)\right]}{1-\underline{s}} \frac{\partial s_L}{\partial q} < 0.$$

The inequality uses that s_L decreases in q as in Proposition 2. Hence, when $\gamma = \gamma_{\min}$, $q^*_{EL} = 0$. By continuity, there exists some cutoff $\gamma_4 > \gamma_{\min}$ such that for $\gamma < \gamma_4$, $q^*_{EL} = 0$. Such a γ_4 is also unique because q^*_{EL} is monotonic in γ, which we will prove later. In sum, if $\gamma \in [\underline{\gamma}, \gamma_4]$, $q^*_{EL} = 0$, whereas if $\gamma \in (\gamma_4, \gamma_1)$, q^*_{EL} solves

$$C'\left(q^*_{EL}\right) = \frac{\tau\left[\beta - (1-\gamma)\right]}{1-\underline{s}}\left(\frac{\partial s_L}{\partial q} - \frac{\partial s_B}{\partial q}\right) + \frac{\alpha - (1-\gamma)}{1-\underline{s}} \int_{s_B}^{1} (1-s)\,ds. \tag{A.14}$$

Finally, we now derive an exogenous condition for the requirement that $q^*_{EL} < \frac{K-(\underline{s}\alpha-\tau\beta)}{\alpha(1-\underline{s})}$ for all $\gamma < \gamma_2$. To do so, we first prove that q_{EL} increases in γ. For the cases of $\gamma \geq \gamma_1$, $q^*_{EL} = q^*_{IL}$ and hence increases in γ by Proposition 3. For $\gamma \in (\gamma_4, \gamma_1)$, applying the implicit function theorem to (A.14) yields that $\frac{\partial q^*_{EL}}{\partial \gamma} > 0$ if and only if

$$\int_{s_B}^{1} (1-s)h(s)\,ds - (1-s_B)(\alpha-(1-\gamma))h(s_B)\frac{\partial s_B}{\partial \gamma} - \frac{\partial^2 s_B}{\partial \gamma \partial q}\tau(\beta-(1-\gamma))h(s_B)$$
$$+ \tau\left(\frac{\partial s_L}{\partial q}h(s_L) - \frac{\partial s_B}{\partial q}h(s_B)\right) - \frac{\partial s_B}{\partial q}\frac{\partial s_B}{\partial \gamma}\tau(\beta-(1-\gamma))h'(s_B) > 0,$$

With the uniform distribution, this condition can be simplified into:

$$\int_{s_B}^{1} (1-s)\,ds + \frac{\tau(\beta-\alpha)\left[\alpha - \tau(1-\gamma)\right]}{(1-q_{EL})^2\alpha\left[\alpha-(1-\gamma)\right]} > 0, \tag{A.15}$$

which is always met. Using the property that q^*_{EL} increases in γ, a sufficient condition for $q^*_{EL} < \frac{K-(\underline{s}\alpha-\tau\beta)}{\alpha(1-\underline{s})}$ in all $\gamma < \gamma_2$ is that

$$q^*_{EL}(\gamma_2) \leq \frac{K - \left(\underline{s}\alpha - \tau\beta\right)}{\alpha\left(1-\underline{s}\right)}, \tag{A.16}$$

where q_{EL} is given in (A.13). Note that the left-hand side of (A.16) is independent of K, whereas the right-hand side of (A.16) increases in K. Consequently, the condition in (A.16) holds if $K \geq \overline{K}$, where $\overline{K}$ solves $q^*_{EL}(\gamma_2) =$

[17] We will prove later that in this case, $\gamma_2 \geq \gamma_1$.

$\frac{\overline{K}-(\underline{s}\alpha-\tau\beta)}{\alpha(1-\underline{s})}$. In addition, note that, using the definition of γ_2, $\gamma_1 > \gamma_2$ is equivalent to $\gamma_1 > \gamma_{\max}(q^*_{IL}(\gamma_2))$, which is equivalent to $q^*_{IL}(\gamma_2) > \frac{K-(\underline{s}\alpha-\tau\beta)}{\alpha(1-\underline{s})}$, plugging in the expression of $\gamma_{\max}$ in (A.3). Thus, $\gamma_1 > \gamma_2$ if and only if $K < \overline{K}$. When $K \geq \overline{K}$, $\gamma_1 \leq \gamma_2$.

In sum, when $K \geq \overline{K}$, we state the equilibrium of q^*_{EL} as follows:

1. $q^*_{EL} = 0$ if $\gamma \in [\underline{\gamma}, \gamma_4]$;
2. q^*_{EL} solves (A.14) and increases in γ if $\gamma \in (\gamma_4, \gamma_1)$;
3. $q^*_{EL} = q^*_{IL}$ and increases in γ if $\gamma \geq \gamma_1$.

Case 2: $K \leq \underline{s}\alpha - \tau\beta$. In this case, $q^*_{EL} \geq \frac{K-(\underline{s}\alpha-\tau\beta)}{\alpha(1-\underline{s})}$ is always satisfied because $q^*_{EL} \geq 0$. In this case, the regulator always liquidates the bank upon asset substitution. The first-order condition (A.12) reduces into:

$$C'\left(q^*_{EL}\right) = \frac{\alpha - (1-\gamma)}{1-\underline{s}} \int_{s_B}^{1} (1-s)\,ds - \frac{\tau\left[\beta - (1-\gamma)\right]}{1-\underline{s}} \frac{\partial s_B}{\partial q}.$$

Suppose that $\gamma \in [\underline{\gamma}, \gamma_{\min}]$, $s_B = 1$ and $q^*_{EL} = 0$. Next, suppose that $\gamma \in (\gamma_{\min}, \gamma_2)$. If $\gamma < \gamma_{\max}(q_{EL})$, $s_B > \underline{s}$ and q^*_{EL} solves

$$C'\left(q^*_{EL}\right) = \frac{\alpha - (1-\gamma)}{1-\underline{s}} \int_{s_B}^{1} (1-s)\,ds - \frac{\tau\left[\beta - (1-\gamma)\right]}{1-\underline{s}} \frac{\partial s_B}{\partial q}. \qquad \text{(A.17)}$$

Hence, the condition that $\gamma < \gamma_{\max}(q_{EL})$ reduces into $\gamma < \gamma_3$, where the cutoff γ_3 solves $\gamma_3 = \gamma_{\max}(q^*_{EL}(\gamma_3))$ and q^*_{EL} is defined as in (A.17). In addition, applying the implicit function theorem to (A.17) yields that $\frac{\partial q^*_{EL}}{\partial \gamma} > 0$ if and only if

$$\int_{s_B}^{1} (1-s)h(s)\,ds + \frac{\tau(1-\tau)(\beta-(1-\gamma))}{(1-q_{EL})^2(\alpha-(1-\gamma))} h(s_B) > 0, \qquad \text{(A.18)}$$

which always holds. Finally, consider the case of $\gamma \in [\gamma_3, \gamma_2)$. Note that in this case, in equilibrium it must be that $s_B = \underline{s}$. To see this, assume by contradiction that $s_B > \underline{s}$. Then q^*_{EL} solves

$$C'\left(q^*_{EL}\right) = \frac{\alpha - (1-\gamma)}{1-\underline{s}} \int_{s_B}^{1} (1-s)\,ds - \frac{\tau\left[\beta - (1-\gamma)\right]}{1-\underline{s}} \frac{\partial s_B}{\partial q}.$$

However, this implies that in equilibrium, $\gamma < \gamma_{\max}(q^*_{EL})$, which yields that $\gamma < \gamma_3$. A contradiction because $\gamma \in [\gamma_3, \gamma_2)$. In addition, the equilibrium cannot be an interior solution to the first-order condition. To see this, assume by contradiction, that q^*_{EL} solves the first-order condition. As $s_B = \underline{s}$, the first-order condition reduces into

$$C'\left(q^*_{EL}\right) = \frac{\alpha - (1-\gamma)}{1-\underline{s}} \int_{\underline{s}}^{1} (1-s)\,ds. \qquad \text{(A.19)}$$

Hence, $q^*_{EL} = q^*_{IL}$. However, $s_B(q^*_{IL}) = \underline{s}$ implies that in equilibrium, $\gamma \geq \gamma_{\max}(q^*_{IL})$, which yields that $\gamma \geq \gamma_2$. A contradiction because $\gamma \in [\gamma_3, \gamma_2)$. Therefore, the only equilibrium in $\gamma \in [\gamma_3, \gamma_2)$ is a corner solution. To derive the equilibrium, note that the condition $s_B(q_{EL}^*) = \underline{s}$ requires that $\gamma \geq \gamma_{\max}(q_{EL}^*)$. Using (A.3), this yields:

$$\gamma \geq \gamma_{\max}(q_{EL}^*) = \frac{\tau(\beta-1) - \left[q_{EL}^* + (1-q_{EL}^*)\underline{s}\right](\alpha-1)}{q_{EL}^* + (1-q_{EL}^*)\underline{s} - \tau},$$

which can be reduced into:

$$q_{EL}^* \geq \frac{\tau\left[\beta-(1-\gamma)\right] - \underline{s}\left[\alpha-(1-\gamma)\right]}{\left(1-\underline{s}\right)\left[\alpha-(1-\gamma)\right]}.$$

Hence, the equilibrium is either $q_{EL}^* = \frac{\tau[\beta-(1-\gamma)]-\underline{s}[\alpha-(1-\gamma)]}{(1-\underline{s})[\alpha-(1-\gamma)]}$ or $q_{EL}^* = 1$. Given our assumption that $C'(1) = \infty$, $q_{EL}^* = 1$ can never be an equilibrium. Hence, $q_{EL}^* = \frac{\tau[\beta-(1-\gamma)]-\underline{s}[\alpha-(1-\gamma)]}{(1-\underline{s})[\alpha-(1-\gamma)]}$ for $\gamma \in [\gamma_3, \gamma_2)$. Note that

$$\frac{\partial}{\partial\gamma}\left(\frac{\tau\left[\beta-(1-\gamma)\right] - \underline{s}\left[\alpha-(1-\gamma)\right]}{\left(1-\underline{s}\right)\left[\alpha-(1-\gamma)\right]}\right) = -\frac{\tau(\beta-\alpha)}{(1-\underline{s})\left[\alpha-(1-\gamma)\right]^2} < 0.$$

In the case of $K \leq \underline{s}\alpha - \tau\beta$, we state the equilibrium of q_{EL}^* as follows:

1. $q_{EL}^* = 0$ if $\gamma \in [\underline{\gamma}, \gamma_{\min}]$;
2. q_{EL}^* solves (A.17) and increases in γ if $\gamma \in (\gamma_{\min}, \gamma_3)$;
3. $q_{EL}^* = \frac{\tau[\beta-(1-\gamma)]-\underline{s}[\alpha-(1-\gamma)]}{(1-\underline{s})[\alpha-(1-\gamma)]}$ and decreases in γ if $\gamma \in [\gamma_3, \gamma_2)$;
4. $q_{EL}^* = q_{IL}^*$ and increases in γ if $\gamma \geq \gamma_2$.

Case 3: $K \in (\underline{s}\alpha - \tau\beta, \overline{K})$. If $\gamma = \gamma_2$, we have $q_{EL}^* > \frac{K-(\underline{s}\alpha-\tau\beta)}{\alpha(1-\underline{s})}$, whereas if $\gamma < \gamma_4$, we have $q_{EL}^* = 0 < \frac{K-(\underline{s}\alpha-\tau\beta)}{\alpha(1-\underline{s})}$ from case 1. From case 1, q_{EL}^* increases in γ as long as $q_{EL}^* < \frac{K-(\underline{s}\alpha-\tau\beta)}{\alpha(1-\underline{s})}$. Hence, there exists a unique $\gamma_0 \in (\gamma_4, \gamma_2)$ such that $q_{EL}^* < \frac{K-(\underline{s}\alpha-\tau\beta)}{\alpha(1-\underline{s})}$ for $\gamma \in (\gamma_{\min}, \gamma_0)$. Following similar analysis in case 1, we can show that if $\gamma \in [\underline{\gamma}, \gamma_4]$, $q_{EL}^* = 0$. Recall from case 1 that when $K < \overline{K}$, $\gamma_1 > \gamma_2 > \gamma_0$. Therefore, if $\gamma \in (\gamma_4, \gamma_0)$, q_{EL}^* solves (A.14). Next, consider the region of $\gamma \geq \gamma_0$ such that $q_{EL}^* \geq \frac{K-(\underline{s}\alpha-\tau\beta)}{\alpha(1-\underline{s})}$. Following similar analysis in case 2, we can show that if $\gamma \in [\gamma_0, \gamma_3)$, q_{EL}^* solves (A.17). If $\gamma \in [\max\{\gamma_0, \gamma_3\}, \gamma_2)$, $q_{EL}^* = \frac{\tau[\beta-(1-\gamma)]-\underline{s}[\alpha-(1-\gamma)]}{(1-\underline{s})[\alpha-(1-\gamma)]}$. In sum, when $K \in (\underline{s}\alpha - \tau\beta, \overline{K})$, we state the equilibrium of q_{EL}^* as follows:

1. $q_{EL}^* = 0$ if $\gamma \in [\underline{\gamma}, \gamma_4]$;
2. q_{EL}^* solves (A.14) and increases in γ if $\gamma \in (\gamma_4, \gamma_0)$;
3. q_{EL}^* solves (A.17) and increases in γ if $\gamma \in [\gamma_0, \gamma_3)$;
4. $q_{EL}^* = \frac{\tau[\beta-(1-\gamma)]-\underline{s}[\alpha-(1-\gamma)]}{(1-\underline{s})[\alpha-(1-\gamma)]}$ and decreases in γ if $\gamma \in [\max\{\gamma_0, \gamma_3\}, \gamma_2)$;
5. $q_{EL}^* = q_{IL}^*$ and increases in γ if $\gamma \geq \gamma_2$.

Finally, we compare q_{IL}^* and q_{EL}^* under the three cases.
Case 1: $K \geq \overline{K}$.

1. If $\gamma \in [\underline{\gamma}, \gamma_{\min}]$, $q_{EL}^* = q_{IL}^* = 0$.
2. If $\gamma \in (\gamma_{\min}, \gamma_4]$, $q_{EL}^* = 0 < q_{IL}^*$.

3. If $\gamma \in (\gamma_4, \gamma_1)$, plugging (A.10) into (A.14) yields:

$$\begin{aligned}
&C'\left(q_{EL}^*\right) - C'\left(q_{IL}^*\right) \\
&= \frac{\tau\left[\beta - (1-\gamma)\right]}{1-\underline{s}}\left(\frac{\partial s_L}{\partial q} - \frac{\partial s_B}{\partial q}\right) \\
&= \frac{\tau\left[\beta - (1-\gamma)\right]}{\left(1-\underline{s}\right)}\frac{\partial}{\partial q}(s_L - s_B) \\
&= -\frac{\tau\left[\beta - (1-\gamma)\right]}{\left(1-\underline{s}\right)}\frac{\tau(\beta-\alpha)(1-\gamma) - K\left[\alpha - (1-\gamma)\right]}{\alpha\left[\alpha-(1-\gamma)\right]}\frac{\partial}{\partial q}\left(\frac{1}{1-q}\right) \\
&= -\frac{\tau\left[\beta - (1-\gamma)\right]}{\left(1-\underline{s}\right)(1-q)^2}\frac{\tau(\beta-\alpha)(1-\gamma) - K\left[\alpha - (1-\gamma)\right]}{\alpha\left[\alpha-(1-\gamma)\right]} \\
&< 0.
\end{aligned}$$

The third step uses (A.5). The last inequality holds if $\gamma < \gamma_1$ by (A.6). As $C'' > 0$, $q_{EL}^* < q_{IL}^*$.

4. If $\gamma \geq \gamma_1$, $q_{EL}^* = q_{IL}^*$.

Case 2: $K \leq \underline{s}\alpha - \tau\beta$.

1. If $\gamma \in [\underline{\gamma}, \gamma_{\min}]$, $q_{EL}^* = q_{IL}^* = 0$.
2. If $\gamma \in (\gamma_{\min}, \gamma_3)$, plugging (A.10) into (A.17) yields:

$$C'\left(q_{EL}^*\right) - C'\left(q_{IL}^*\right) = -\frac{\tau\left[\beta - (1-\gamma)\right]}{1-\underline{s}}\frac{\partial s_B}{\partial q} > 0.$$

The last step uses that $\frac{\partial s_B}{\partial q} \leq 0$. As $C'' > 0$, $q_{EL}^* > q_{IL}^*$.

3. If $\gamma \in [\gamma_3, \gamma_2)$, $q_{EL}^* = \frac{\tau[\beta-(1-\gamma)]-\underline{s}[\alpha-(1-\gamma)]}{(1-\underline{s})[\alpha-(1-\gamma)]}$ such that $s_B(q_{EL}^*) = \underline{s}$ and $s_B(q_{IL}^*) \in (\underline{s}, 1)$. Recall that from Proposition 1, s_B decreases in q. As $s_B(q_{IL}^*) > s_B(q_{EL}^*) = \underline{s}$, $q_{EL}^* > q_{IL}^*$.
4. If $\gamma \geq \gamma_2$, $q_{EL}^* = q_{IL}^*$.

Case 3: $K \in (\underline{s}\alpha - \tau\beta, \overline{K})$.

1. If $\gamma \in [\underline{\gamma}, \gamma_{\min}]$, $q_{EL}^* = q_{IL}^* = 0$.
2. If $\gamma \in (\gamma_{\min}, \gamma_4]$, $q_{EL}^* = 0 < q_{IL}^*$.
3. If $\gamma \in (\gamma_4, \gamma_0)$, $q_{EL}^* < q_{IL}^*$ following similar analysis in case 1.
4. If $\gamma \in [\gamma_0, \gamma_3)$, $q_{EL}^* > q_{IL}^*$ following similar analysis in case 2.
5. If $\gamma \in [\max\{\gamma_0, \gamma_3\}, \gamma_2)$, $q_{EL}^* > q_{IL}^*$ following similar analysis in case 2.
6. If $\gamma \geq \gamma_2$, $q_{EL}^* = q_{IL}^*$.

In sum, if $\gamma \in [\underline{\gamma}, \gamma_{\min}]$, $q_{EL}^* = q_{IL}^* = 0$; if $K \leq \underline{s}\alpha - \tau\beta$, $q_{EL}^* \geq q_{IL}^*$; if $K \geq \overline{K}$, $q_{EL}^* \leq q_{IL}^*$; if $K \in (\underline{s}\alpha - \tau\beta, \overline{K})$ and $\gamma \geq \gamma_{\min}$, $q_{EL}^* < q_{IL}^*$ if and only if $\gamma < \gamma_0$.

A.8 PROOF OF PROPOSITION 5

We compare $W_{IL}(\gamma)$ and $W_{EL}(\gamma)$ under the first two cases listed in the proposition as the last case follows directly from Corollary 1.

Case 1: $\gamma \in [\underline{\gamma}, \gamma_{\min}]$. From Proposition 4, $q^*_{EL} = q^*_{IL} = 0$. From Corollary 2, fixing the risk choice at $q^*_{EL} = q^*_{IL} = 0$, $W_{EL} > W_{IL}$. In addition, suppose that $K \leq \underline{s}\alpha - \tau\beta$. From Proposition 4, $q^*_{EL} \geq q^*_{IL}$ for all γ. Using (A.7) and (A.8), we obtain:

$$W_{EL}(q^*_{EL}, \gamma) - W_{IL}\big(q^*_{IL}, \gamma\big) \geq W_{EL}(q^*_{IL}, \gamma) - W_{IL}\big(q^*_{IL}, \gamma\big) \geq 0. \tag{A.20}$$

The first step uses that W_{EL} increases in q. To see this, note that

$$\frac{\partial W_{EL}}{\partial q} = \frac{E}{\gamma}\left[\int_{s_B}^{1} (1-s)\alpha h(s)\,ds - \frac{\partial s_B}{\partial q} K h(s_B)\right] > 0.$$

The first equality uses that when $K \leq \underline{s}\alpha - \tau\beta$, $s_L = \underline{s}$. The second inequality uses $\frac{\partial s_B}{\partial q} < 0$. The second step of (A.20) follows from Corollary 2.

Case 2: $K \geq \overline{K}$ and $\gamma > \gamma_{\min}$. Recall from Corollary 1 that for $\gamma \geq \gamma_1$, the two loan loss models yield the same equilibrium outcome, that is, $W_{EL}(q^*_{EL}, \gamma) = W_{IL}(q^*_{IL}, \gamma)$. Hence, we focus on deriving a sufficient condition such that $W_{IL}(\gamma) > W_{EL}(\gamma)$ in the region of $\gamma \in (\gamma_{\min}, \gamma_1)$. For the ease of notation, we will present the proof using A instead of γ. Consider a small neighborhood of $A \in (A_1, A_1 + \varepsilon)$, where $\varepsilon > 0$ is arbitrarily small. A_1 is such that $A_1 = \frac{E}{\gamma_1}$. We have

$$\begin{aligned}
& W_{IL}(A) - W_{EL}(A) \\
&= W_{IL}(A_1) - W_{EL}(A_1) + \varepsilon \lim_{A \to A_1^+}\left(\frac{\partial W_{IL}}{\partial A} - \frac{\partial W_{EL}}{\partial A}\right) \\
&= \varepsilon \lim_{A \to A_1^+}\left(\frac{\partial W_{IL}}{\partial A} - \frac{\partial W_{EL}}{\partial A}\right) \\
&= \varepsilon \lim_{A \to A_1^+}\Bigg(\Bigg(\int_{\underline{s}}^{s_B} \tau\beta h(s)\,ds + \int_{s_B}^{1} \big(s + (1-s)q^*_{IL}\big)\alpha h(s)\,ds - 1 \\
&\quad + A\left(\frac{\partial s_B}{\partial A} + \frac{\partial q^*_{IL}}{\partial A}\frac{\partial s_B}{\partial q}\right)\big(\tau\beta - \big(s_B + (1-s_B)q^*_{IL}\big)\alpha\big)h(s_B) + A\frac{\partial q^*_{IL}}{\partial A}\int_{s_B}^{1}(1-s)\alpha h(s)\,ds \\
&\quad - \left(\int_{\underline{s}}^{s_L} \tau\beta h(s)\,ds + \int_{s_L}^{1}\big(s + (1-s)q^*_{EL}\big)\alpha h(s)\,ds - \int_{s_L}^{s_B} K h(s)\,ds - 1\right) \\
&\quad - A\,\frac{\partial q^*_{EL}}{\partial A}\int_{s_L}^{1}(1-s)\alpha h(s)\,ds + A\left(\frac{\partial s_B}{\partial A} + \frac{\partial q^*_{EL}}{\partial A}\frac{\partial s_B}{\partial q}\right)K h(s_B)\Bigg) \\
&= \varepsilon A_1 \lim_{A \to A_1^+}\Bigg(\left(\frac{\partial q^*_{IL}}{\partial A} - \frac{\partial q^*_{EL}}{\partial A}\right)\int_{s_B}^{1}(1-s)\alpha h(s)\,ds \\
&\quad + \left(\frac{\partial s_B}{\partial A} + \frac{\partial q^*_{EL}}{\partial A}\frac{\partial s_B}{\partial q}\right)K h(s_B) + \left(\frac{\partial s_B}{\partial A} + \frac{\partial q^*_{IL}}{\partial A}\frac{\partial s_B}{\partial q}\right)\big(\tau\beta - \big(s_B + (1-s_B)q^*_{IL}\big)\alpha\big)h(s_B)\Bigg) \\
&= \varepsilon A_1 \lim_{A \to A_1^+}\left(\left(\frac{\partial q^*_{IL}}{\partial A} - \frac{\partial q^*_{EL}}{\partial A}\right)\left(\int_{s_B}^{1}(1-s)\alpha h(s)\,ds - \frac{\partial s_B}{\partial q}K\right)\right).
\end{aligned}$$

The first step uses a Taylor approximation. The second step uses $W_{EL}(A_1) = W_{IL}(A_1)$. The fourth step uses $q^*_{EL}(A_1) = q^*_{IL}(A_1)$ and $s_B(A_1) = s_L(A_1)$. The fifth step uses that, at $A = A_1$, we have $s = s_L = s_B$ and

$$\left[s_B + (1 - s_B)q\right]\alpha = \tau\beta + K.$$

Moreover, at $A = A_1$, q^*_{IL} and q^*_{EL} are continuous in A, and $q^*_{IL} = q^*_{EL}$. Furthermore, if $A \in (A_1, A_{\max})$, $\gamma < \gamma_1$ such that from Proposition 4, $q^*_{IL} > q^*_{EL}$. This, in turn, yields:

$$\lim_{A \to A_1^+} \left(\frac{\partial q^*_{IL}}{\partial A} - \frac{\partial q^*_{EL}}{\partial A}\right) = \frac{1}{\varepsilon}\left(q^*_{IL}(A_1 + \varepsilon) - q^*_{EL}(A_1 + \varepsilon)\right) > 0.$$

Finally, $\frac{\partial s_B}{\partial q} < 0$ and $\int_{s_B}^1 (1 - s)\alpha h(s)\,ds > 0$. Hence, if $K \geq \overline{K}$ and $\gamma \in (\gamma_1 - \varepsilon, \gamma_1)$, $W_{IL}(\gamma) > W_{EL}(\gamma)$. Without loss of generality, define γ_W such that for $\gamma \in [\gamma_W, \gamma_1)$, $W_{IL}(\gamma) > W_{EL}(\gamma)$.

A.9 PROOF OF PROPOSITION 6

We provide some additional details of the first-order condition (21) and (24) that supplement the analysis in the main text. Taking the derivative of (A.7) with respect to γ gives that:

$$\begin{aligned}
\frac{\partial W_{IL}(\gamma)}{\partial \gamma} &= -\frac{E}{\gamma^2}\left(\int_{\underline{s}}^{s_B} \tau\beta h(s)\,ds + \int_{s_B}^1 \left[s + (1 - s)q^*_{IL}\right]\alpha h(s)\,ds - 1\right) \\
&\quad + \frac{E}{\gamma}\left(\frac{\partial s_B}{\partial \gamma} + \frac{\partial q^*_{IL}}{\partial \gamma}\frac{\partial s_B}{\partial q}\right)\left[\tau\beta - \left(s_B + (1 - s_B)q^*_{IL}\right)\right]\alpha h(s_B) \\
&\quad + \frac{E}{\gamma}\frac{\partial q^*_{IL}}{\partial \gamma}\int_{s_B}^1 (1 - s)\alpha h(s)\,ds. \qquad \text{(A.21)}
\end{aligned}$$

Taking the derivative of (A.8) with respect to γ gives that:

$$\begin{aligned}
\frac{\partial W_{EL}(\gamma)}{\partial \gamma} &= -\frac{E}{\gamma^2}\left(\int_{\underline{s}}^{s_L} \tau\beta h(s)\,ds + \int_{s_L}^1 \left(s + (1 - s)q^*_{EL}\right)\alpha h(s)\,ds - \int_{s_L}^{s_B} K h(s)\,ds - 1\right) \\
&\quad + \frac{E}{\gamma}\frac{\partial q^*_{EL}}{\partial \gamma}\frac{\partial s_L}{\partial q}\left(\tau\beta + K - \left(s_L + (1 - s_L)q^*_{EL}\right)\alpha\right)h(s_L) \\
&\quad + \frac{E}{\gamma}\frac{\partial q^*_{EL}}{\partial \gamma}\int_{s_L}^1 (1 - s)\alpha h(s)\,ds - \frac{E}{\gamma}\left(\frac{\partial s_B}{\partial \gamma} + \frac{\partial q^*_{EL}}{\partial \gamma}\frac{\partial s_B}{\partial q}\right)K h(s_B) \\
&= -\frac{E}{\gamma^2}\left(\int_{\underline{s}}^{s_L} \tau\beta h(s)\,ds + \int_{s_L}^1 \left(s + (1 - s)q^*_{EL}\right)\alpha h(s)\,ds - \int_{s_L}^{s_B} K h(s)\,ds - 1\right) \\
&\quad + \frac{E}{\gamma}\frac{\partial q^*_{EL}}{\partial \gamma}\int_{s_L}^1 (1 - s)\alpha h(s)\,ds - \frac{E}{\gamma}\left(\frac{\partial s_B}{\partial \gamma} + \frac{\partial q^*_{EL}}{\partial \gamma}\frac{\partial s_B}{\partial q}\right)K h(s_B). \qquad \text{(A.22)}
\end{aligned}$$

The second step uses that $\tau\beta + K = s_L + (1 - s_L)q^*_{EL}$.

A.10 PROOF OF COROLLARY 3

The corollary follows directly from case 1 of Proposition 5.

A.11 PROOF OF PROPOSITION 7

Note that if $K \leq \underline{s}\alpha - \tau\beta$, from Proposition 5, $W_{EL}(\gamma) \geq W_{IL}(\gamma)$. It follows directly that $W_{EL}(\gamma^*_{EL}) \geq W_{IL}(\gamma^*_{IL})$.

We now derive sufficient conditions so that $\gamma^*_{EL} < \gamma^*_{IL}$. For the ease of notation, we will present the proof using the bank size $A \equiv \frac{E}{\gamma}$ instead of the capital ratio γ. We define A_2 (resp. A_3) such that $A_2 = \frac{E}{\gamma_2}$ (resp. $A_3 = \frac{E}{\gamma_3}$). We first prove two preliminary results that we will use in our future steps:

Result 1: For $A \leq A_2$, $W_{IL} = W_{EL}$. In particular, $\lim_{A \to A_2^-} \frac{\partial W_{IL}}{\partial A} = \lim_{A \to A_2^-} \frac{\partial W_{EL}}{\partial A}$.

Result 1 follows directly from the fact, that, for $A \leq A_2$, the bank does not asset-substitute.

Result 2: $\lim_{A \to A_2^-} \frac{\partial W_{IL}}{\partial A} > \lim_{A \to A_2^+} \frac{\partial W_{IL}}{\partial A}$ and $\lim_{A \to A_2^+} \frac{\partial W_{EL}}{\partial A} > 0$.

The first part of result 2 holds because

$$\lim_{A \to A_2^-} \frac{\partial W_{IL}}{\partial A} - \lim_{A \to A_2^+} \frac{\partial W_{IL}}{\partial A} \tag{A.23}$$

$$= A\left(\frac{\partial s_B}{\partial A} + \frac{\partial q^*_{IL}}{\partial A}\frac{\partial s_B}{\partial q}\right)\left(\left[s_B + (1-s_B)q^*_{IL}\right]\alpha - \tau\beta\right)h(s_B) - A\frac{\partial q^*_{IL}}{\partial A}\int_{\underline{s}}^{1}(1-s)\alpha h(s)\,ds > 0.$$

The first equality uses the first-order conditions (A.21) and (A.22). The last inequality holds because $\frac{\partial q^*_{IL}}{\partial A} < 0$, $\frac{\partial s_B}{\partial A} > 0$ and $\frac{\partial s_B}{\partial q} < 0$. The second part of result 2 holds because, for any $A \in (A_2, A_3]$, we have

$$\lim_{A \to A_2^+} \frac{\partial W_{EL}}{\partial A} = \int_{\underline{s}}^{1}\left[s + (1-s)q^*_{EL}\right]\alpha h(s)\,ds - 1 + A\frac{\partial q^*_{EL}}{\partial A}\int_{\underline{s}}^{1}(1-s)\alpha h(s)\,ds > 0.$$

The last inequality holds because, for $A \in (A_2, A_3]$, $q^*_{EL} = \frac{\tau[\beta-(1-\gamma)]-\underline{s}[\alpha-(1-\gamma)]}{(1-\underline{s})[\alpha-(1-\gamma)]}$ and $\frac{\partial q^*_{EL}}{\partial A} > 0$.

Given results 1 and 2, we derive some sufficient conditions for $A^*_{EL} > A^*_{IL}$, that is, $\gamma^*_{EL} < \gamma^*_{IL}$. We proceed in two steps. In step 1, we prove that $\lim_{A \to A_2^+} \frac{\partial W_{IL}}{\partial A} < 0$ is a sufficient condition for $A^*_{EL} > A^*_{IL}$. In step 2, we reduce the condition $\lim_{A \to A_2^+} \frac{\partial W_{IL}}{\partial A} < 0$ into a condition on $h(\underline{s})$.

Step 1: We prove that $\lim_{A \to A_2^+} \frac{\partial W_{IL}}{\partial A} < 0$ is a sufficient condition for $A^*_{EL} > A^*_{IL}$. By Assumption 8, $\lim_{A \to A_2^+} \frac{\partial W_{EL}}{\partial A} > 0$ implies that for $A \leq A_2$, $\frac{\partial W_{EL}}{\partial A} > 0$. Therefore, $A^*_{EL} > A_2$. In addition, $\lim_{A \to A_2^+} \frac{\partial W_{IL}}{\partial A} < 0$ implies that for $A > A_2$, $\frac{\partial W_{IL}}{\partial A} < 0$. Furthermore,

$$\frac{\partial W_{IL}}{\partial A}\Big|_{A=A_2^-} = \frac{\partial W_{EL}}{\partial A}\Big|_{A=A_2^-} = \int_{\underline{s}}^{1}\left[s + (1-s)q^*_{EL}\right]\alpha h(s)\,ds - 1 > 0. \tag{A.24}$$

The first equality uses result 1 and the second equality uses the definition of W_{EL}. By Assumption 9, for $A < A_2$, $\frac{\partial W_{IL}}{\partial A} > 0$. Therefore, $A^*_{IL} = A_2$, which implies that $A^*_{EL} > A_2 = A^*_{IL}$.

Step 2: We show that $\lim_{A \to A_2^+} \frac{\partial W_{IL}}{\partial A} < 0$ if $h(\underline{s})$ is sufficiently large. We have

$$\lim_{A \to A_2^+} \frac{\partial W_{IL}}{\partial A}$$

$$= \lim_{A \to A_2^+} \Bigg(\int_{\underline{s}}^{s_B} \tau\beta h(s)\,ds + \int_{s_B}^{1} \big(s + (1-s)q_{IL}^*\big)\alpha h(s)\,ds - 1$$

$$+ A\left(\frac{\partial s_B}{\partial A} + \frac{\partial q_{IL}^*}{\partial A}\frac{\partial s_B}{\partial q}\right)\big(\tau\beta - \big(s_B + (1-s_B)q_{IL}^*\big)\alpha\big)h(s_B) + A\frac{\partial q_{IL}^*}{\partial A}\int_{s_B}^{1}(1-s)\alpha h(s)\,ds\Bigg)$$

$$= \int_{\underline{s}}^{1} \big(s + (1-s)q_{IL}^*\big)\alpha h(s)\,ds - 1$$

$$+ A_2 \lim_{A \to A_2^+}\left(\left(\frac{\partial s_B}{\partial A} + \frac{\partial q_{IL}^*}{\partial A}\frac{\partial s_B}{\partial q}\right)\big(\tau\beta - \big(\underline{s} + (1-\underline{s})q_{IL}^*\big)\alpha\big)h(\underline{s}) + \frac{\partial q_{IL}^*}{\partial A}\int_{s_B}^{1}(1-s)\alpha h(s)\,ds\right)$$

$$< \int_{\underline{s}}^{1} \big(s + (1-s)q_{IL}^*\big)\alpha h(s)\,ds - 1 - A_2 \lim_{A \to A_2^+}\left(\frac{\partial s_B}{\partial A} + \frac{\partial q_{IL}^*}{\partial A}\frac{\partial s_B}{\partial q}\right)\big(\underline{s}\alpha - \tau\beta\big)h(\underline{s})$$

$$< \alpha - 1 - A_2 \lim_{A \to A_2^+} \frac{\partial s_B}{\partial A}\big(\underline{s}\alpha - \tau\beta\big)h(\underline{s}).$$

The second equality uses $s_B(A_2) = \underline{s}$. The third step uses $\frac{\partial q_{IL}^*}{\partial A} < 0$ and $(\underline{s} + (1-\underline{s})q_{IL}^*)\alpha > \underline{s}\alpha$. The last step uses $\int_{\underline{s}}^{1}(s + (1-s)q_{IL}^*)h(s)\,ds < 1$ and $\frac{\partial q_{IL}^*}{\partial A} < 0$. Note that the last term is negative if

$$h(\underline{s}) > \frac{\alpha - 1}{A_2 \lim_{A \to A_2^+} \frac{\partial s_B}{\partial A}\big(\underline{s}\alpha - \tau\beta\big)} = \frac{\alpha - 1}{A_2 \frac{\tau(\beta-\alpha)E}{(1-q_{IL}^*)(\alpha A_2 - (A_2 - E))^2}\big(\underline{s}\alpha - \tau\beta\big)}.$$

This is satisfied if

$$h(\underline{s}) > \frac{\alpha - 1}{\frac{\tau(\beta-\alpha)}{\alpha}\big(\underline{s}\alpha - \tau\beta\big)}.$$

Hence, if $h(\underline{s})$ is sufficiently large, then $\lim_{A \to A_2^+} \frac{\partial W_{IL}}{\partial A} < 0$. By continuity, there exists some thresholds $\{\bar{s}, \underline{h}\}$, such that, if $\Pr(s < \bar{s}) = \int_{\underline{s}}^{\bar{s}} h(s)\,ds > \underline{h}$ and $K \leq \underline{s}\alpha - \tau\beta$, $\gamma_{EL}^* < \gamma_{IL}^*$. Numerical analysis confirms that the set of parameters that satisfy these conditions is nonempty.

APPENDIX B: Loan Losses Provisioning and Capital Ratio

We now provide an implementation of loan loss provisioning accounting standards under CECL in the context of our model. In particular, we show how provisioning for loan losses affects the bank's balance sheet and capital ratio.[18] We use the notations E_t and A_t to denote the carrying values of the bank's equity and assets at date $t \in \{0, 1\}$, respectively.

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[18] We are grateful to Mary Barth and Alexander Nezlobin, who encouraged us to better connect our model to the practical implementation of an EL such as CECL.

At $t = 0$, the value of the bank's assets $A_0 = E + D = A$ and the value of the bank's equities $E_0 = E$. The regulatory capital requirements thus require that:[19]

$$\frac{E_0}{A_0} = \frac{E}{A} = \gamma. \tag{B.1}$$

At $t = 1$, after learning the early information s, the bank takes provision for loan losses in accordance with the accounting rules. Under the IL, because the bank delays the recognition of loan losses, its asset and equity values are unchanged, that is, $A_1 = A$ and $E_1 = E$. The bank continues to satisfy the regulatory capital requirements,

$$\frac{E_1}{A_1} = \frac{E}{A} = \gamma. \tag{B.2}$$

As a result, the regulator cannot intervene at $t = 1$ under the IL.

The recognition of loan losses under the EL, however, differs substantially from that under the IL because the EL "forces banks to recognize expected future losses immediately," sometimes even at origination.[20] In particular, FASB Accounting Standards Update No. 2016-13 states that, upon initial measurement, "the entity shall discount expected cash flows at the financial asset's effective interest rate," and "the allowance for credit losses shall reflect the difference between the amortized cost basis and the present value of the expected cash flows." (FASB, 2016, paragraph 326-20-30-4). Under the EL, the bank therefore accounts for the expected change s in the default risk and measures the value of the loan by discounting the expected future cash flows from the loan ($A\alpha[s + (1 - s)q]$) using the loan's effective interest rate ($\alpha - 1$):

$$A_1 = \frac{A\alpha\big[s + (1 - s)q\big]}{1 + \alpha - 1} = A\big[s + (1 - s)q\big]. \tag{B.3}$$

Comparing A_1 to A_0 implies that the balance of the allowance for loan losses, $A_0 - A_1 = A(1 - [s + (1 - s)q])$. Provisioning for loan losses, in

[19] Bank regulators may also use other types of regulation based on the bank's balance sheet, such as some risk-weighted measure of assets to regulate capital. By Basel II and III, assets are partitioned into different groups based on their risk and these different groups are assigned different weights. Adding an additional risk-weighted capital constraint in our model, however, will not alter any of our results. This is because, as shown in our main analysis, with only the leverage requirements, the regulator already implements the ex post optimal intervention policy. Adding another regulatory constraint hence alters neither the regulator's intervention decisions nor the bank's decisions.

[20] See https://bpi.com/cecl-regulatory-capital-proposal-leaves-many-important-questions-unanswered/.

turn, reduces the bank's equity to $E_1 = E - A(1 - [s + (1 - s)q])$ so that the bank's capital ratio changes to

$$\frac{E_1}{A_1} = \frac{E - A\big(1 - \big[s + (1 - s)q\big]\big)}{A - A\big(1 - \big[s + (1 - s)q\big]\big)} < \frac{E}{A} = \gamma. \tag{B.4}$$

That is, under the EL, reporting s at $t = 1$ causes a violation of the regulatory capital requirements that, in turn, triggers regulatory intervention.