Rules versus Discretion in Capital Regulation*

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Abstract

We study capital regulation in a dynamic model for bank deposits. Capital regulation addresses banks' incentive for excessive leverage that dilutes depositors, but preserves some dilution to reduce bank defaults. We show theoretically that capital regulation is subject to a time inconsistency problem. In a model with non-maturing deposits where optimal withdrawals make deposits endogenously long-term, we find commitment to have important effects on the optimal level and cyclicality of capital adequacy. Our theory is consistent with cross-country changes in capital regulation around the 2008 financial crisis and calls for a systematic framework that limits capital regulators' discretion.

Keywords: capital regulation, time inconsistency, non-maturing deposits, dilution.
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1 Introduction

Capital requirements are the cornerstone of bank regulation. They play a crucial role in safeguarding the stability of banking systems and protecting depositors and other creditors. While policy makers have been focusing for a long time on designing the optimal rules for required capital ratios, such as categorizing capital into different tiers and introducing asset risk weights, one of the key innovations of Basel III is to grant banks the ability to adjust capital requirements dynamically by changing capital buffers on top of required capital ratios. The academic literature has mostly studied capital requirements that are fixed or based on ad hoc policy rules. An important but largely overlooked fact is that macroprudential authorities have substantial discretion regarding when, by how much, and for how long capital buffers shall be adjusted, which is quite different from required capital ratios formulated as rules.

As emphasized by the Committee on the Global Financial System (2016), the discretion over capital requirements can potentially bring to capital regulators the classic time inconsistency problem faced by monetary authorities (Kydland and Prescott, 1977).[1] Following the advice by the Basel Committee on Banking Supervision (2010), certain regulators have already made preliminary attempts to bound their discretion over capital requirements. For instance, the EU Capital Requirements Directive (Article 136(7)) requires national authorities reducing capital buffers to communicate for how long they expect to not increase it again, and several EU economies have already put such macroprudential "forward guidance" to use.[2] Despite the concerns and actions of regulators, whether or how a time inconsistency problem is relevant for capital regulation is not quite understood. Discretion is not necessarily value destroying. A clear understanding of these issues is important for policy making.

[1]Different from the discussions about bailouts or too-big-to-fail, the time inconsistency of capital requirements is about whether regulators with discretionary power would ex post deviate from a stringency of capital requirements that is ex ante optimal for welfare. See a panel on the rule-versus-discretion issue of Basel III's capital regulation framework in Atlanta Fed's 2013 Financial Markets Conference: https://www.atlantafed.org/news/conferences-and-events/conferences/2013/0408-fmc/media/rules-vs-discretion-transcript.

[2]For instance, the Bank of Italy explained in its 2015 Financial Stability Report that it was unlikely to increase the countercyclical capital buffer in 2016. Following the reduction of the countercyclical capital buffer rate to 0% in July 2016, the Bank of England advised that absent of any changes in economic outlook, it expected to maintain the rate for at least a year. See Kowalik (2011) for a policy work comparing rule-based and discretionary implementations of countercyclical capital buffers.

For instance, if a low capital buffer remains optimal at a future date after it gets reduced today, the above-mentioned "forward guidance" is redundant under rational expectation; if not, a countercyclical capital buffer will not be enforced effectively unless regulators take serious actions to bound the discretion they have.

In this paper, we provide the first analysis of the time inconsistency problem associated with bank capital regulation. Banks create value by issuing deposits that provide liquidity benefits. We show that time inconsistency arises if deposits are defaultable and long-term. According to the FDIC, about half of US bank deposits are uninsured.[3] Meanwhile, a large proportion of them have a long maturity—they include not only non-maturing deposits without an explicit maturity date that are typically not withdrawn for extended periods, but also time deposits and wholesale deposits that have a fixed long maturity.[4] Deposit value reflects risk-adjusted future payments, and therefore, with a long maturity, future leverage of a bank will have an effect on current deposit value as it determines the riskiness of payments not yet received at that point. With this, we show that being able to commit to future leverage matters for today. In contrast, banks in typical macro-finance models are financed either with short-term defaultable deposits that fully mature before bank leverage tomorrow gets decided, or with insured deposits. This leads to simplified dynamic structures and implies that future bank leverage does not affect deposit value today.

Our analysis is organized into two parts. First, we present a baseline model where deposit maturity is long but fixed, following existing studies on corporate debt maturity. This setup allows maximal transparency to establish our theoretical results about a regulator's time inconsistency problem. Second, we consider an extended model with non-maturing deposits a la Jermann and Xiang (2023) to reflect a key difference between typical corporate debt with fixed maturity and bank deposits. In particular, a large amount of deposits have no explicit maturity dates, and depositors' withdrawals make deposits endogenously long-term. The recent failure of the Silicon Valley Bank (SVB) has highlighted the importance of uninsured deposit withdrawals for bank stability. We numerically solve the extended model and show the long-run level (steady states) and dynamics of optimal policies of regulators with different

[3] Maechler and McDill (2006), Egan, Hortaçsu and Matvos (2017), and Martin, Puri and Ufier (2022) find that uninsured deposits are indeed sensitive to bank default risks.

[4] There is a growing literature that emphasizes the long-term nature of bank deposits, including e.g. Drechsler, Savov and Schnabl (2021), Jermann and Xiang (2023), and Bolton, Li, Wang and Yang (Forthcoming).

levels of commitment.

We start with our baseline model with fixed deposit maturity. In laissez-faire, banks maximize equity value only and therefore do not internalize that new deposit issuance can dilute the value of legacy deposits by exposing them to a higher default risk. Such an equity-debt conflict implies an incentive for banks to take an leverage that is excessive from social perspective and has been recognized by policy makers (e.g. Tucker, 2013; Yellen, 2015) and academics (e.g. Admati and Hellwig, 2014) to be one important motivation for capital regulation.[5]

A capital regulator who maximizes social welfare takes into account all stakeholders, i.e. the total value of banks and depositors. By correcting the dilution incentive of banks, capital requirements improve the total value that can be generated. However, banks have the option to default when the equity value becomes too low. Therefore, optimal leverage policy preserves some dilution. This is because the value of deposits represents banks' debt burden, and dilution of depositors is thus valuable for reducing dead-weight costs of bank defaults.

We show theoretically the value of regulatory commitment to future capital requirements. We compare the problem of a Ramsey regulator who can commit to future policies and that of a Markov-perfect regulator who cannot. A Markov-perfect regulator understands that preserving dilution persuades banks today to not default, but does not internalize that it also persuades banks yesterday to not default. This is because with long maturity, deposit value yesterday declines when depositors back then rationally expect dilution today to reduce risk-adjusted payments. With such dynamic externality, a regulator has a tendency to adopt an excessively low leverage. To formalize this, we allow a Markov-perfect regulator in steady state to commit in one shot to deposit issuance tomorrow, and we prove that it has an incentive to deviate upward from the steady-state level. By committing to an amount of deposits that become ex-post suboptimally high after banks have decided to not default today, banks' debt burden and thus defaults today get reduced. Overall, committing to future leniency in capital requirements allows a regulator to better prevent bank defaults.

We also consider regulators with two types of partial commitment, i.e. one commits to

[5] Jermann and Xiang (2023) show that the presence of deposit insurance can in fact worsen the agency conflict between banks and uninsured depositors in the laissez-faire economy. In particular, the government bears all the price impact of issuing insured deposits. Therefore, holders of uninsured deposits can be expropriated more easily as their banks can now dilute them by issuing insured deposits.

bank equity values only and another commits to deposit values only. Such regulators have less (more) commitment power than Ramsey (Markov-perfect) who commits to both (none). We allow a partial commitment regulator in steady state to commit in one shot to deposit issuance tomorrow, and we prove that it does not have an incentive to deviate. While such additional commitment power helps a Markov-perfect regulator to improve total value today at the cost of total value tomorrow, we show that once either equity or deposit values can be committed, maximizations of total values today and tomorrow become dynamically consistent. In line with this, we find that the optimal steady-state policies of regulators with partial commitment are identical to that of Ramsey. Our result indicates that while adding one type of credible commitments can be quite effective in aligning a capital regulator's incentives at different points in time, adding a second one can encounter drastically diminishing returns in the long run. It also suggests that the ability to make credible commitments is more important than to whom such commitments are made—banks or depositors.

The deviation by the Markov-perfect regulator induced by a one-shot commitment indicates from a theoretical standpoint that the optimal policies of a Ramsey regulator who has full commitment will be different from theirs. In the second part of our analysis, we numerically solve the problems of Ramsey and Markov-perfect regulators to show precisely these differences. We use local methods that can solve the steady states with essentially no approximation error. We do so in an extended setup featuring non-maturing deposits, i.e., deposits have no explicit maturity dates and are demandable. Individual depositors decide whether to withdraw at a cost each period when liquidity shocks realize. Deposits are endogenously long-term as depositors getting a low liquidity shock will choose to not withdraw. We establish two sets of key results.

First, we find that optimal leverage and bank default risk in steady state critically depend on regulatory commitment. As usual, commitment leads to better outcomes. However, this does not necessarily imply a lower leverage and fewer bank defaults. Being able to better prevent defaults brings a Ramsey regulator a better tradeoff between liquidity and default costs. The regulator finds it optimal to issue a large amount of deposits for the purpose of liquidity creation despite a slightly higher probability of default. We find that the steady state equity ratio under a Ramsey regulator can even be lower than laissez-faire, which is in sharp contrast to typical models of capital requirements. Overall, a regulator who can prevent default efficiently using commitment does not worry about taking leverage. We compare the baseline model with a fixed deposit maturity and the extended model with non-maturing deposits. While results are qualitatively similar across the two, we find that endogenous withdrawals can amplify quantitatively the value of commitment because bank leverage tomorrow has an additional effect on deposit withdrawals today.

Second, we compare Ramsey and Markov-perfect regulators' responses to aggregate shocks. We find that commitment leads to a stronger countercyclicality in optimal policy. Facing a negative productivity shock, banks have a larger incentive to default. A Ramsey regulator not only loosens capital requirements today but also commits to extend such leniency for a long time. This is useful for resolving bank defaults on impact. In contrast, a Markov-perfect regulator rapidly tightens up its policy as leniency starts to imply too much risk and becomes suboptimal fairly quickly as productivity reverts back. Our result suggests that bounding the ability of regulators to quickly increase capital buffers once reduced, as attempted by the EU Capital Requirements Directive, is indeed useful.

We complement our theory by examining cross-country changes in capital regulation stringency around the 2008 global financial crisis. First, we find that a GDP contraction during crisis led to more lenient capital requirements post crisis for countries more likely having a welfare-maximizing government. This is consistent with our theoretical result that regulators restrict leverage in normal times to protect depositors but allow a temporarily high leverage to alleviate banks' stronger default incentives caused by a negative shock, whereas banks in laissez-faire take a leverage that has equity value always maximized and therefore do not benefit from pushing it up further upon the shock. Second, we proxy for commitment using a rule of law index that describes the constraints imposed on government power by non-government entities, and we show that among welfare-maximizing governments, a GDP contraction during crisis led to more lenient capital requirements post crisis for those exhibiting more commitment.[6] This is consistent with our theoretical result that a Ramsey regulator extends leniency for longer than a Markov-perfect regulator.

Literature—There is a large literature on macro-finance banking models that evaluates

[6]In the post-crisis decade, governments worldwide had substantial discretion over capital stringency, beyond what Basel III's design of capital buffers simply brings. For instance, given the massive purchase of bank shares during the crisis, governments had to decide on how quickly banks would have to buy them back. Furthermore, even among Basel members, each country sets its own pace regarding the adoption of Basel III's more stringent standards. Gropp et al. (2024) document the forbearance of EU national regulators when their domestic banks inflate regulatory capital to meet supranational rules, i.e. the 2011 Capital Exercise by the European Banking Authority.

macroprudential policies, mostly bank capital requirements. Optimal macroprudential regulation in dynamic models has been derived by Chari and Kehoe (2016), Davydiuk (2017), Bianchi and Mendoza (2018), Malherbe (2020), Schroth (2021), and Van der Ghote (2021). A large number of studies examine the impact of exogenous capital requirement rules, such as Van den Heuvel (2008), Angeloni and Faia (2013), Repullo and Suarez (2013), Mendicino, Nikolov, Suarez and Supera (2018), Begenau (2020), Gertler, Kiyotaki and Prestipino (2020), Corbae and D'Erasmo (2021), Elenev, Landvoigt and Van Nieuwerburgh (2021), Begenau and Landvoigt (2022), and Xiang (2022). Different from these studies which typically focus on one-period debt and feature distortions from government subsidies, our analysis features long-term debt and the resulting equity-debt conflict, i.e. dilution. Importantly, we also explicitly study a capital regulator's commitment issues.

There is a growing literature that studies the rich dynamics of firms that are financed with long-term debt—see e.g. Gomes, Jermann and Schmid (2016), Crouzet (2017), Admati, DeMarzo, Hellwig and Pfleiderer (2018), Gamda and Saretto (2018), DeMarzo and He (2021), Benzoni, Garlappi, Goldstein and Ying (2022), Jungherr and Schott (2022), Jermann and Xiang (2023), and Xiang (2024).[7] While this literature has been focusing on the problem of a borrower, we study a new problem, that is, that of a regulator who cares about the total resources in the economy rather than just the borrowers'. Dilution can be good for the regulator to address borrowers' option to default.[8] Quite different from the key insight of existing studies that borrowers' welfare increases if they could commit to dilute less, we highlight that social welfare increases if a Markov-perfect regulator could commit to dilute more.

An unusual property of our model is that the Ramsey allocation features non-stationary Lagrange multipliers together with stationary real variables. This is reminiscent of characterizations in the optimal taxation literature where convergence of multipliers cannot always be established; see e.g. Straub and Werning (2020) or Chien and Wen (2022). Bassetto and Cui (Forthcoming) solve a Ramsey tax problem and find a stationary allocation together with non-stationary multipliers.

The paper proceeds as follows. Section 2 presents our baseline model of capital regulators

[7] Aguiar, Amador, Hopenhayn and Werning (2019) and Hatchondo, Martinez and Roch (2020) derive optimal debt paths for a sovereign borrower.

[8] Donaldson, Gromb and Piacentino (Forthcoming) show that dilution can be good for borrowers to loosen borrowing constraints when there is an asset pledgeability issue.

with different levels of commitment. Section 3 shows theoretically the value of commitment. Section 4 presents an extended model with non-maturing deposits and numerically solves optimal policies. Section 5 provides empirical evidence. Section 6 concludes.

2 Model

In this section, we present our baseline model with fixed deposit maturity. Section 2.1 describes the laissez-faire economy. Section 2.2 describes the problem of capital regulators. We use lowercase for variables of individual banks and uppercase for aggregate variables.

2.1 Laissez-faire

2.1.1 Banks and depositors

Time is discrete. All agents are risk-neutral. The economy is populated with a continuum of banks, each of which faces a continuum of depositors and creates value by providing liquidity services. Individual i holding b_i unit of deposits earns a liquidity benefit of μb_i, e.g. for using the bank account for day-to-day transactions. We assume that μ is decreasing in the aggregate amount of deposits in the economy $B = \int_{i\in[0,1]^2} b_i di$, that is, $\frac{\partial \mu(B)}{\partial B} < 0$. This assures that a Ramsey regulator in our infinite-horizon setup cannot create an infinitely large liquidity value by issuing an infinite amount of deposits and is typical for macro models with deposits in utility (e.g. Van den Heuvel, 2008).[9] Deposit maturity is $1/\lambda$, that is, each period $\lambda \in (0, 1]$ fraction of deposits get matured. Both liquidity value and debt maturity will be determined by the endogenous withdrawals of depositors in our model with non-maturing deposits.

The assets of a bank generate a per-period profit of $R + z$. We fix aggregate productivity R in our baseline analysis. z is a zero-mean bank-specific i.i.d. productivity shock with c.d.f. (p.d.f.) $\Phi(z)$ ($\phi(z)$) over support $[-\bar{z}, \bar{z}]$. Taking as given the law of motion for aggregate deposits B, i.e. $B' = \Omega(B)$, an individual bank's equity value and optimal policy

[9] These models typically feature a concave utility function over consumption goods and deposits. We directly account for the marginal value of holding deposits in the form of consumption goods, i.e. $\mu(B)$. Together with the assumption that all agents are risk neutral with respect to consumption goods, this implies that social welfare can be represented by discounted total resources. Regulators' tradeoff exhibits maximal transparency.

in laissez-faire are given by:

$$z + v^e(B,b) = z + \max_{b'} \Big\{ R - \lambda b + q(B,b')[b' - (1-\lambda)b] + \frac{1}{r}\Big\{ \int_{-v^e(B',b')}^{\bar{z}} [v^e(B',b') + z'] d\Phi(z') \Big\} \Big\}, \quad (1)$$

where legacy deposits for the bank is $b = \int_{i\in[0,1]} b_i di$ and interest rate is r. Banks take the deposit pricing schedule $q(B,b')$ as given when choosing b'. Bank equity value consists of profits $R+z$, repayment to matured deposits λb, proceeds from issuing new deposits $q[b' - (1-\lambda)b]$, and the continuation value which incorporates the bank's default option tomorrow. A bank defaults if its equity value tomorrow goes below zero, i.e. $z' + v^e(B',b') < 0$.

Deposit pricing function $q(B,b')$ is pinned down by the zero-profit condition of new depositors. For a non-defaulting bank, the payoff to depositors in the current period consists of liquidity value μb, repayment to matured deposits λb, and the value of unmatured deposits $q(1-\lambda)b$. That is, depositors' value is given by:

$$v^b(B,b,q) = [\mu(B) + \lambda + q(1-\lambda)]b.$$

For defaulting banks, our formulation follows Gomes, Jermann and Schmid (2016). Upon default, depositors take over the bank and initiate a restructuring. They first sell off the equity portion to new owners while continuing to hold their deposits. This means that depositors have a claim over the total bank franchise value $z + v^e + v^b$ in defaulting states. However, they incur a dead-weight restructuring loss of ξb. Under this formulation, we do not need to track the cross-sectional distribution of deposits when considering the aggregate economy from the perspective of a regulator. We have, given $B' = \Omega(B)$,

$$q(B,b')b' = \frac{1}{r}\Big\{ \int_{-v^e(B',b')}^{\bar{z}} v^b(B',b',q(B',h_b(B',b')))d\Phi(z') + \int_{-\bar{z}}^{-v^e(B',b')} [z' + v^e(B',b') + v^b(B',b',q(B',h_b(B',b'))) - \xi b']d\Phi(z') \Big\}, \quad (2)$$

where optimal policy $b' = h_b(B,b)$ solves (1). If deposit maturity is long, i.e. $\lambda < 1$, deposit price tomorrow $q(B', h_b(B', b'))$ enters the equation, through which deposit price today will depend on the issuance decision of the bank's tomorrow self.

2.1.2 Equilibrium

Given deposits $\{b\}_{[0,1]}$, asset profits $\{z\}_{[0,1]}$, law of motion for aggregate deposits $B' = \Omega(B)$, and a deposit pricing schedule, banks choose whether to default and, if not, the amount of new deposits to issue.

An equilibrium of the laissez-faire economy is defined as a set of functions for (i) banks' deposit issuance policy $h_b(B, b)$ and equity value $z + v^e(B, b)$ given by (1); (ii) deposit pricing schedule $q(B, b')$ given by (2); (iii) banks' optimal default set $\{z | z + v^e(B, b) < 0\}$; (iv) bank's deposit issuance policy is consistent with law of motion for B, i.e. $\Omega(B) = h_b(B, B)$.

2.2 Capital regulators

The notation of the laissez-faire economy presented in the previous section mostly carries through. As we consider aggregates, we shift to uppercase letters B, Q, L, V^e and V^b. Section 2.2.1 lays out the planning problem of a Ramsey regulator. Section 2.2.2 describes the corresponding problem of a Markov-perfect regulator without commitment. Section 2.2.3 present two regulators with partial commitment as intermediate cases in between.

2.2.1 Ramsey regulator

By construction, we can measure social welfare in our model using total resources of the economy. A Ramsey regulator chooses allocations at $t = 0$ to maximize the present value of total resources, taking as given banks' default rule, depositors' zero-profit condition, and an initial B_0. Aggregate resources each period consist of three parts. First, bank assets provide constant profits R with i.i.d. z shocks averaged out. Second, bank deposits provide liquidity value $\mu(B_t)B_t$. Third, a certain fraction of banks default, which produces a total default cost of $\xi B_t \Phi(-V_t^e)$. A Ramsey regulator's problem is thus given by

$$\max_{\{V_t^e, Q_t, B_{t+1}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \frac{1}{r^t} \left[R + \mu(B_t)B_t - \xi B_t \Phi(-V_t^e) \right].$$

Optimal choices have to satisfy a series of constraints on equity values

$$V_t^e = R - \lambda B_t + Q_t[B_{t+1} - (1-\lambda)B_t] + \frac{1}{r}\left[\int_{-V_{t+1}^e}^{\bar{z}} (z + V_{t+1}^e)d\Phi(z)\right],$$

and on deposit prices

$$Q_t B_{t+1} = \frac{1}{r}\left[\int_{-V_{t+1}^e}^{\bar{z}} V_{t+1}^b d\Phi(z) + \int_{-\bar{z}}^{-V_{t+1}^e} (z + V_{t+1}^e + V_{t+1}^b - \xi B_{t+1})d\Phi(z)\right],$$

for all $t \geq 0$, where depositors' value is $V_t^b = [\mu(B_t) + \lambda + (1-\lambda)Q_t]B_t$. In addition, there are two no-Ponzi conditions, i.e. $\lim_{t\to\infty} \frac{B_t}{r^t} = 0$ and $\lim_{t\to\infty} \frac{V_t^e}{r^t} = 0$, and one no-bubble condition, i.e. $\lim_{t\to\infty} \frac{Q_t}{r^t} = 0$.

The following proposition characterizes the solution to this sequential problem by splitting it into a continuation problem and an initial problem. The continuation problem can be represented recursively and leads to definitions of problems with no and partial commitment later.

Proposition 1 *An interior allocation of the Ramsey problem in Section 2.2.1 is identical to that of the following problem. A regulator chooses deposits B', promised equity value $V^{e\prime}$ and promised deposit price Q' at $t \geq 0$ following:*

$$H(B, V^e, Q) = \max_{B', V^{e\prime}, Q'} R + \mu(B)B - \xi B\Phi(-V^e) + \frac{1}{r}H(B', V^{e\prime}, Q'),$$

subject to two promise keeping constraints:

$$V^e = R - \lambda B + Q[B' - (1-\lambda)B] + \frac{1}{r}\left[\int_{-V^{e\prime}}^{\bar{z}} (z' + V^{e\prime})d\Phi(z')\right], \tag{3}$$

and

$$QB' = \frac{1}{r}\left\{\int_{-V^{e\prime}}^{\bar{z}} V^b(B', Q')d\Phi(z') + \int_{-\bar{z}}^{-V^{e\prime}} [z' + V^{e\prime} + V^b(B', Q') - \xi B']d\Phi(z')\right\}, \tag{4}$$

where depositors' value is $V^b(B, Q) = [\mu(B) + \lambda + Q(1-\lambda)]B$.

Initially, given B_0, the regulator chooses:

$$\max_{V_0^e, Q_0} H(B_0, V_0^e, Q_0).$$

Choice sets of the regulator are consistent with no-Ponzi and no-bubble conditions.

Proof. See Appendix A.1. ■

In the continuation problem, in addition to the natural state variables B, the Ramsey regulator is bound by two auxiliary state variables—promises made about bank equity value V^e and deposit price Q. Past promises constrain the regulator's behavior and can support choices that might not be optimal ex post conditional on B only (Kydland and Prescott, 1980). Every period, the Ramsey regulator chooses next period's deposit level B' and makes promises for next period's equity value $V^{e\prime}$ and deposit price Q'.[10] Initially, V_0^e and Q_0 are chosen without being constrained by past promises.

2.2.2 Markov-perfect regulator

Based on the recursive characterization of the Ramsey problem, we define the problem of a Markov-perfect regulator as having neither of the two auxiliary state variables in the continuation problem. The Markov-perfect regulator shares the objective function with Ramsey but faces only the natural state variables B. Therefore, it has full discretion regarding what to choose at each point in time. There is no need to split the problem into two given the initial problem and the continuation problem follow the same structure.

Given deposits B, a Markov-perfect regulator solves:

$$H(B) = \max_{B'} \ R + \mu(B)B - \xi B \Phi\left(-V^e(B, B')\right) + \frac{1}{r} H(B'), \tag{5}$$

[10]When we allow shocks to R, e.g. for our model with non-maturing deposits later, these promises will be state-contingent, i.e., the Ramsey regulator picks a separate pair of $\{V^{e\prime}, Q'\}$ for each R' tomorrow in the continuation problem.

where bank equity value is given by:

$$V^e(B,B') = R - \lambda B + Q(B')[B' - (1-\lambda)B] \\ + \frac{1}{r}\left\{\int_{-V^e(B',h_B(B'))}^{\bar{z}} [z' + V^e(B', h_B(B'))]d\Phi(z')\right\}, \quad (6)$$

and deposit price is given by:

$$Q(B')B' = \frac{1}{r}\left\{\int_{-V^e(B',h_B(B'))}^{\bar{z}} V^b(B', Q(h_B(B')))d\Phi(z') \\ + \int_{-\bar{z}}^{-V^e(B',h_B(B'))} [z' + V^e(B', h_B(B')) + V^b(B', Q(h_B(B'))) - \xi B']d\Phi(z')\right\}, \quad (7)$$

where depositors' value is $V^b(B,Q) = [\mu(B) + \lambda + Q(1-\lambda)]B$; $B' = h_B(B)$ is the optimal policy that solves (5), which the current regulator takes as given.

2.2.3 Partial-commitment regulators

Following the two polar cases, i.e. Ramsey with full commitment and Markov-perfect with no commitment, we now present two intermediate cases. The difference between Ramsey and Markov-perfect is that the former faces two auxiliary state variables—prior promises about bank equity value and deposit price—after the initial period while the latter faces none. Each of our two regulators with partial commitment has only one of the two auxiliary state variables in the continuation problem. In the first economy, the regulator commits to bank equity values only while deposit prices are set in a time-consistent way. In the second economy, the regulator commits to deposit prices only while bank equity values are set in a time-consistent way. Presumably, committing to either equity values or deposit prices would be less involved in practice than committing to both. Therefore, how these partial commitment cases are different from the Ramsey case is of interest for policy making.

The problem of a regulator committing to bank equity values can be split into a continuation problem and an initial problem. The continuation problem is given recursively:

$$H(B, V^e) = \max_{B', V^{e\prime}} R + \mu(B)B - \xi B\Phi(-V^e) + \frac{1}{r}H(B', V^{e\prime}), \quad (8)$$

subject to promise keeping to equity value V^e:

$$V^e = R - \lambda B + Q(B', V^{e\prime})[B' - (1-\lambda)B] + \frac{1}{r}\left[\int_{-V^{e\prime}}^{\bar{z}} (V^{e\prime} + z')d\Phi(z')\right], \tag{9}$$

given a deposit pricing schedule:

$$\begin{aligned} Q(B', V^{e\prime})B' = \frac{1}{r}\bigg\{ &\int_{-V^{e\prime}}^{\bar{z}} V^b(B', Q(h_B(B', V^{e\prime}), h_{V^e}(B', V^{e\prime})))d\Phi(z') \\ &+ \int_{-\bar{z}}^{-V^{e\prime}} [z' + V^{e\prime} + V^b(B', Q(h_B(B', V^{e\prime}), h_{V^e}(B', V^{e\prime}))) - \xi B']d\Phi(z')\bigg\}, \end{aligned} \tag{10}$$

where depositors' value is $V^b(B,Q) = [\mu(B)+\lambda+(1-\lambda)Q]B$; optimal policies $B' = h_B(B, V^e)$ and $V^{e\prime} = h_{V^e}(B, V^e)$ together solve (8).

Initially, given B_0, the regulator chooses:

$$\max_{V_0^e} H(B_0, V_0^e).$$

The problem of a regulator committing to deposit prices can be formulated in a similar way. In the continuation problem, taking as given B, Q and an equity valuation schedule $V^e(B', Q'; B, Q)$, the regulator chooses deposits B' and promised deposit price Q' subject to promise keeping to deposit price Q. Initially, the regulator picks Q_0 given B_0. To save space, this problem is presented in Appendix B.

3 Capital regulation and commitment

We now demonstrate the value of commitment to a capital regulator. Section 3.1 explains how long-term defaultable deposits create a role for capital regulation. Section 3.2 explains why they also imply a time inconsistency problem for a regulator. Section 3.3 contrasts the time inconsistency problem of a regulator against that of banks, the latter of which has been the focus of existing literature. Section 3.4 analyzes the effect of partial commitment.

3.1 Banks' dilution and capital regulation

In laissez-faire, banks maximize their equity value. In typical models of one-period defaultable debt, the equity-value-maximizing objective does not impair social welfare. This is because all legacy debt have to be repaid before banks can issue new debt, who therefore internalize all benefits and costs that result from their issuance decisions. With long-term debt, banks make decisions with the presence of legacy debt, and they do not internalize that issuing new debt will dilute the value of legacy debt by exposing them to additional default risks. This classic equity-debt conflict creates a static externality that impairs social welfare.

More specifically, let's consider the steady state of the laissez-faire economy in which aggregate B and thus μ are constant. An individual bank's problem is

$$z + v^e(b) = z + \max_{b'} \left\{ R - \lambda b + q(b')[b' - (1-\lambda)b] + \frac{1}{r}\int_{-v^e(b')}^{\bar{z}} [z' + v^e(b')] d\Phi(z') \right\}, \tag{11}$$

where deposit price satisfies

$$q(b')b' = \frac{1}{r}\left\{ [\mu + \lambda + (1-\lambda)q(h_b(b'))]b' + \int_{-\bar{z}}^{-v^e(b')} [z' + v^e(b') - \xi b'] d\Phi(z') \right\}, \tag{12}$$

and optimal policy $h_b(b)$ solves (11).

Differentiate bank's objective in (11) with respect to deposit choice b':

$$q(b') + [b' - (1-\lambda)b]\frac{\partial q(b')}{\partial b'} + [1 - \Phi(-v^e(b'))]\,\frac{1}{r}\frac{\partial v^e(b')}{\partial b'} = 0. \tag{13}$$

The first two terms together capture the marginal benefit from new issuance proceeds today. The third term is the marginal cost reflecting a larger repayment tomorrow.[11] With $q(b')$ being typically decreasing in well-behaved models, the second term corresponds to a negative price impact of issuance—that is, a larger repayment pressure leads to a higher default risk tomorrow and thus a lower price $q(b')$ today at which *new* deposits $b' - (1-\lambda)b$ can be issued. Importantly, this means that banks do not internalize that *legacy* deposits $(1-\lambda)b$ also bear part of the default risk and encounter a value decline, which is reflected by the dilution term

[11] By envelope theorem, we know: $\frac{\partial v^e(b)}{\partial b} = -\lambda - (1-\lambda)q(h_b(b)) < 0$.

$-(1-\lambda)b\frac{\partial q(b')}{\partial b'}$ in (13). Due to this externality, banks have the tendency to issue an amount of deposits that is excessive from the perspective of maximizing social welfare. By doing so, the increased default risk reduces the present value of future payments to legacy deposits, i.e. the debt burden for banks, and benefits equity value.[12]

Proposition 2 connects the problem of a capital regulator with that of laissez-faire banks. While laissez-faire banks maximize equity value v^e (or its monotone transformation $v^e - \xi B\Phi\left(-v^e\right)$), a regulator also takes into account the value of legacy deposits V^b. Capital regulation improves social welfare by correcting the equity-value-maximizing objective of banks.[13] Moreover, all regulators share a total-value-maximizing objective after the initial period, and therefore, any potential difference between their steady-state policies reflects only their different degrees of commitment power.

Proposition 2 *In equilibrium, total value created by a Ramsey capital regulator in the continuation problem is*

$$H(B,V^e,Q) = V^e + V^b(B,Q) - \xi B\Phi(-V^e). \tag{14}$$

Total value created by a Markov-perfect capital regulator is

$$H(B) = V^e\left(B, h_B(B)\right) + V^b(B, Q(h_B(B))) - \xi B\Phi\left(-V^e\left(B, h_B(B)\right)\right), \tag{15}$$

with $h_B(B)$ being its policy function.

Total value created by a capital regulator with partial commitment to equity values in the continuation problem is

$$H(B,V^e) = V^e + V^b(B, Q(h_B(B,V^e), h_{V^e}(B,V^e))) - \xi B\Phi(-V^e) \tag{16}$$

[12]Formally, bank's objective in (11) can be rewritten into $R-[\lambda+(1-\lambda)q(b')]b+S(b')$ where $S(b')$ is the discounted value of banks and all depositors in laissez-faire. Starting from the choice for b' that maximizes $S(b')$, a marginal increase in b' will affect $S(b')$ only in a second-order way according to the envelope theorem. However, the value accrued to legacy depositors $(1-\lambda)q(b')b$ declines in a first-order way if $q(b')$ is strictly decreasing. On net, this implies an increase in equity value.

[13]In addition, since we have assumed that liquidity value $\mu(B)$ decreases in B in order to bound the problem of a Ramsey regulator, regulators improve welfare also by internalizing that adopting a smaller B improves $\mu(B)$. In Section 4.3, we solve our model and find this channel to play a relatively minor role as regulated economies admit a much larger B than laissez-faire.

with $h_B(B, V^e)$ and $h_{V^e}(B, V^e)$ being its policy functions.

Proof. For the Ramsey regulator, plug (4) into (3) and we get $V^e + [\lambda + (1-\lambda)Q]B = R + \frac{1}{r}[V^{e\prime} + V^b(B', Q') - \xi B'\Phi(-V^{e\prime})]$. Conjecture (14) to hold, and we can then rewrite the objective into $V^e + V^b(B, Q) - \xi B\Phi(-V^e)$. We have verified our conjecture.

For the Markov-perfect regulator, plug (7) into (6) and we get $V^e(B, B') + [\lambda + (1-\lambda)Q(B')]B = R + \frac{1}{r}\left[V^e(B', h_B(B')) + V^b(B', Q(h_B(B'))) - \xi B'\Phi(-V^e(B', h_B(B')))\right]$. Conjecture (15) to hold, and we can then rewrite the objective into $V^e(B, B') + V^b(B, Q(B')) - \xi B\Phi\left(-V^e\left(B, B'\right)\right)$. At optimum $B' = h_B(B)$, and we have verified our conjecture.

For the partial-commitment regulator, plug (10) into (9), and we get $V^e + [\lambda + (1-\lambda)Q(B', V^{e\prime})]B = R + \frac{1}{r}[V^{e\prime} + V^b(B', Q(h_B(B', V^{e\prime}), h_{V^e}(B', V^{e\prime}))) - \xi B'\Phi(-V^{e\prime})]$. Conjecture (16) to hold, and we can then rewrite the objective into $V^e + V^b(B, Q(B', V^{e\prime})) - \xi B\Phi(-V^e)$. At optimum $B' = h_B(B, V^e)$ and $V^{e\prime} = h_{V^e}(B, V^e)$, and we have verified our conjecture. ■

3.2 Regulator's time inconsistency problem

Now we describe the tradeoff faced by a regulator and show that optimal capital regulation suffers a time inconsistency problem. Sharing the same objective, a regulator can create a larger total value by committing to deposit issuance that no longer remains optimal as time evolves.

Consider the problem of a Markov-perfect regulator without any commitment:

$$H(B) = \max_{B'} \ R + \mu(B)B - \xi B\Phi\left(-V^e\left(B, B'\right)\right) + \frac{1}{r}H(B'), \tag{17}$$

where bank equity value (after plugging (7) into (6) and then simplifying using (15)) is:

$$V^e(B, B') = R - \lambda B - Q(B')(1-\lambda)B + \frac{1}{r}H(B'), \tag{18}$$

and deposit price is given by:

$$Q(B')B' = \frac{1}{r}\Bigg\{[\mu(B') + \lambda + (1-\lambda)Q(h_B(B'))]B' + \int_{-\bar{z}}^{-V^e(B',h_B(B'))} [z' + V^e(B', h_B(B')) - \xi B']d\Phi(z')\Bigg\}, \tag{19}$$

where optimal policy $h_B(B)$ solves (17).

Differentiate the Markov-perfect regulator's objective in (17) with respect to deposit choice B':

$$\Bigg[-(1-\lambda)B\frac{\partial Q(B')}{\partial B'} + \frac{1}{r}\frac{\partial H(B')}{\partial B'}\Bigg]\xi B\phi(-V^e(B,B')) + \frac{1}{r}\frac{\partial H(B')}{\partial B'} = 0. \tag{20}$$

The first term describes how B' reduces default costs today through elevating bank equity value $V(B,B')$. The second term describes how it affects total value tomorrow. The presence of the dilution term $-(1-\lambda)B\frac{\partial Q(B')}{\partial B'}$ reflects that the regulator does not want to fully eliminate dilution. This is because banks have the option to default, and thus diluting banks' debt burden can still be valuable. With $Q(B')$ being typically decreasing in well-behaved models, this term is positive.

Capital regulation eliminates the static externality caused by banks' equity-value-maximizing objective, i.e. dilution is allowed only when it improves total value today. However, there is still a dynamic externality, because allowing dilution can also improve total value yesterday. In particular, the value of legacy deposits yesterday declines when depositors back then rationally expect today's dilution to reduce the expected payment to them, i.e. Q's are intertemporally connected in (19) when $\lambda < 1$. The Markov-perfect regulator does not internalize such a positive impact of current dilution on its past self and therefore has the tendency to under-issue relative to social optimum.

Formally, the Markov-perfect regulator's objective described by (17) increases in total value tomorrow $H(B')$ but decreases in deposit price today $Q(B')$. Both terms are forward-looking and take into account the issuance decision of the regulator tomorrow, i.e. $B'' = h_B(B')$. Let's consider an experiment where we give the Markov-perfect regulator a one-shot opportunity today to choose B''. This essentially gives the Markov-perfect regulator some commitment power. According to the envelope theorem, a small deviation to $B'' > h_B(B')$

will affect total value tomorrow only in a second-order way because at $B'' = h_B(B')$ total value tomorrow is already maximized. However, this deviation can reduce deposit price tomorrow when $Q(.)$ is decreasing, which in turn, with $\lambda < 1$, reduces deposit price today in a first-order way. On net, total value today increases. Proposition 3 formalizes the above reasoning and establishes the time inconsistency problem of a capital regulator.

Proposition 3 *In an interior steady state, a Markov-perfect regulator improves total value today by committing to a small one-shot deviation to a larger issuance tomorrow if (i) deposit pricing function is locally downward sloping, i.e.* $\frac{\partial Q(B')}{\partial B'}|_{B'=B_{ss}} < 0$ *where subscript ss denotes steady state values and (ii) deposit maturity is long, i.e.* $\lambda < 1$.

Proof. See Appendix A.2. ■

To sum up, committing to a large deposit issuance in the future serves as a useful tool for a regulator to prevent bank defaults today. A regulator with such an ability, e.g. Ramsey, can create liquidity benefits by incurring smaller default costs. This implies a more efficient tradeoff.

3.3 Comparing regulator's and banks' time inconsistencies

It is worth comparing the time inconsistency problem of a capital regulator that we have established in the previous section and the time inconsistency problem of a borrower that has been examined by the existing literature. The latter is sometimes called a "dilution problem" or a "leverage ratchet effect", and it describes how a borrower's lack of commitment impairs its own welfare (e.g. Gomes, Jermann and Schmid, 2016; Admati, DeMarzo, Hellwig and Pfleiderer, 2018). Some studies have further derived optimal policies for a borrower with commitment, i.e. allocations that maximize a borrower's welfare (e.g. Aguiar, Amador, Hopenhayn and Werning, 2019; Hatchondo, Martinez and Roch, 2020). The objective of capital regulation is not to help borrowers only. Therefore, our investigation of optimal regulation is different from the existing literature.

To recap the time inconsistency of borrowers, banks in our case, let's consider a one-shot commitment opportunity for banks similar to that in Section 3.2 for the Markov-perfect regulator. In steady state, banks issue new deposits every period, i.e. $b' - (1 - \lambda)b > 0$.

A bank's objective described by (11) today increases in equity value tomorrow $v^e(b')$ and deposit price today $q(b')$. Both terms are forward-looking and take into expectation the issuance decision of bank tomorrow, i.e. $b'' = h_b(b')$. Let's give an individual bank a one-shot opportunity today to choose b''. According to the envelope theorem, a small deviating to $b'' < h_b(b')$ will affect equity value tomorrow only in a second-order way because at $b'' = h_b(b')$ equity value tomorrow is already maximized. However, this deviation can increase deposit price tomorrow when $q(.)$ is decreasing, which in turn, with $\lambda < 1$, increases deposit price today in a first-order way. On net, equity value today increases. Proposition 4 echoes Proposition 3 and establishes the time inconsistency problem of banks.

Proposition 4 *In an interior steady state, a laissez-faire bank improves equity value today by committing to a small one-shot deviation to a lower issuance tomorrow if (i) deposit pricing function is locally downward sloping, i.e.* $\frac{\partial q(b')}{\partial b'}|_{b'=b_{ss}} < 0$ *where subscript ss denotes steady state values and (ii) deposit maturity is long, i.e.* $\lambda < 1$.

Proof. See Appendix A.3. ■

Why is an increase in deposit issuance tomorrow good for enhancing equity value today under a Markov-perfect regulator but bad under laissez-faire banks? The difference is driven by the fact that equity value decreases in deposit price conditioning on total value tomorrow (Equation (18)), but increases in deposit price conditioning on equity value tomorrow (Equation (11) when $b' - (1 - \lambda)b > 0$). An increase in issuance tomorrow always reduces the price of long-term deposits today, however, it improves equity value today at the point where total value tomorrow is maximized but reduces equity value today at the point where equity value tomorrow is maximized. Intuitively, to elevate equity value at time t, one should enhance the value of newly issued deposits $B_{t+1} - (1 - \lambda)B_t > 0$. The Markov-perfect regulator at time $t + 1$ protects the value of all deposits B_{t+1}—for the purpose of enhancing equity value at time t, it should instead dilute the value of legacy deposits $(1 - \lambda)B_t$ by choosing a higher B_{t+2}. In contrast, a bank at time $t + 1$ takes into account none of the deposits then existing—for the purpose of enhancing equity value at time t, it should instead protect the value of newly issued deposits $B_{t+1} - (1 - \lambda)B_t$ by choosing a lower B_{t+2}.

3.4 Partial commitment

In the two partial commitment cases, regulators have less power than Ramsey to control future deposit issuance because they can put one fewer promise keeping constraint on their future selves. Interestingly, however, we numerically solve the steady states of the three models and find them to be identical. This result implies that, in steady state, one type of commitment is sufficient to align regulators' incentives across time, moving aggregate quantities from the Markov-perfect to the Ramsey level.

The intuition is as follows. Our result in Section 3.2 implies that for the Markov-perfect regulator, issuance decisions that maximize future total value are not consistent with maximizing current total value. To see why such a dynamic inconsistency is absent for the partial commitment regulator, one shall first recognize the fact that total value combines equity and deposit values—Proposition 2 shows that total value $H = V^e + V^b(B,Q) - \xi B\Phi(-V^e)$ and is increasing in both V^e and Q. In the continuation problem of a regulator committing partially to equity values, with V^e committed previously together with B, it can maximize total value only by maximizing deposit price Q. Moreover, based on the deposit pricing equation, i.e.

$$QB' = \frac{1}{r}\left[V^b(B',Q') + \int_{-\bar{z}}^{-V^{e\prime}} (z' + V^{e\prime} - \xi B')d\Phi(z')\right],$$

fixing choice variables B' and $V^{e\prime}$, decisions by the future regulator that achieve maximal Q' imply maximal Q, and there is no other forward-looking term that can potentially create a misalignment between objectives today and tomorrow. Similarly, in the continuation problem of a regulator committing partially to deposit prices, with Q committed previously together with B, it can maximize total value only by maximizing equity value V^e. Based on the equity value equation, i.e.

$$V^e = R - \lambda B + Q[B' - (1-\lambda)B] + \frac{1}{r}\left[\int_{-V^{e\prime}}^{\bar{z}} (V^{e\prime} + z')d\Phi(z')\right],$$

fixing state variables B, Q and choice variables B', decisions by the future regulator that achieve maximal $V^{e\prime}$ imply maximal V^e, and there is no other forward-looking term that can potentially create a misalignment between objectives today and tomorrow.

Formally, Proposition 5 allows the regulator with partial commitment to equity values to commit today to a small one-shot deviation in B'' away from its steady state level B_{ss} while fixing $B' = B_{ss}$. It shows that such additional commitment power does not improve total value today.[14] This is consistent with our findings that steady states of this partial commitment regulator is identical to that of Ramsey, even though Ramsey has more commitment power.

Proposition 5 *In an interior steady state with $\lambda < 1$, a regulator with partial commitment to equity values cannot improve total value today by committing to a small one-shot deviation in issuance tomorrow if $\frac{\partial Q(B', V^e_{ss})}{\partial B'}|_{B'=B_{ss}} \neq -\frac{Q_{ss}[1-\Phi_{ss}+(\xi B_{ss}\phi_{ss}+\Phi_{ss})\lambda]}{B_{ss}[1-\Phi_{ss}+1-\lambda+(\xi B_{ss}\phi_{ss}+\Phi_{ss})\lambda]\lambda}$ where subscript ss denotes steady state values.*

Proof. See Appendix A.4. ■

In general, we find the allocations of the Ramsey regulator and two regulators with partial commitment to be different. This is because in the initial period there are no prior promises. Consider the regulator with partial commitment to equity values. Equity value V_0^e is not previously committed, and this means that a maximal Q_0 does not necessarily correspond to a maximal H_0. Future regulator's decisions that achieve maximal Q_1 might not be optimal for today.

Overall, our analysis shows that while it is fairly valuable to have one type of credible promises that a regulator can make, adding a second one can encounter strongly diminishing returns in the long run. Interpreting a commitment to equity values as a commitment to bank shareholders and a commitment to deposit prices as a commitment to depositors or other debt holders of banks, our result suggests that a regulator can be very effective without cultivating close relations with both groups. For instance, a close relation to banks' shareholders or managers would be sufficient in the long run from this perspective. The ability to make credible commitments is more important than to whom such commitments are made.

[14] Once B' and B'' gets decided, promise-keeping constraints today and tomorrow pin down $V^{e\prime}$ and $V^{e\prime\prime}$. The inequality condition imposed on the steady-state pricing derivative, which can be verified numerically, rules out a knife-edge scenario where two promise keeping constraints are linearly dependent locally. Otherwise, there are multiple combinations of $\{V^{e\prime}, V^{e\prime\prime}\}$ that can satisfy promise keeping for a given choice of $\{B', B''\}$, making the one-shot deviation problem not well-identified.

4 Model with non-maturing deposits

In the previous section, we have proven that a one-shot commitment induces a Markov-perfect regulator to deviate from its optimal decisions. This indicates that the optimal policy of a Ramsey regulator who has even more commitment power will be different from that of a Markov-perfect regulator and is thus not time consistent. In this section, we numerically solve these optimal policies and show precisely how they are different.

We solve for an extended model with non-maturing deposits. This captures a key feature of bank deposits that distinguishes them from corporate debt with fixed maturity. In particular, a major portion of US bank deposits have no explicit maturity dates and depositors withdraw on demand. This implies that the effective deposit maturity is endogenously changing. Nonetheless, we find our results to be qualitatively similar when solving for our baseline model with fixed deposit maturity. While we are able to analytically show the value of commitment in this extended setup, analogous to Propositions 3, 4, and 5 for our baseline model, we delegate these results to Appendix C in order to focus on the new set of results coming out of model solutions.

Section 4.1 describes laissez-faire, Ramsey- and Markov-perfect-regulated economies.[15] Section 4.2 describes our numerical methods and parameter choices. Section 4.3 compares steady states. Section 4.4 compares impulse responses to a negative aggregate shock.

4.1 Setup

The extended model differs from our baseline in Section 2 in two aspects. First, we allow shocks to aggregate productivity, i.e. $R' = (1-\rho_R)R^* + \rho_R R + \sigma_R \tilde{u}$ where R^* is the average productivity and $\tilde{u} \sim \mathcal{N}(0,1)$. Second, we relax the assumption that deposit maturity is fixed but instead model the optimal withdrawals of bank depositors following Jermann and Xiang (2023). Deposits have no explicit maturity dates, and depositors withdraw on demand to satisfy liquidity needs. In this setting, deposit maturity $1/\lambda$ and liquidity benefits of deposits are endogenous.

[15] Appendix C.2 confirms for this extended setup that a regulator committing partially to equity values in steady state does not deviate when granted a one-short commitment to deposit issuance tomorrow, similar to our baseline in Section 3.4. Steady states of partial-commitment regulators are the same as that of Ramsey. These cases are thus omitted in this section to save space.

4.1.1 Laissez-faire

The liquidity benefit derived by depositor i with deposits b_i consists of two components. First, as in the baseline model, there is a benefit $\mu(B)$ of holding deposits within the period for day-to-day transactions with $\mu(.)$ being decreasing. Second, at the end of each period a liquidity shock hits, and upon withdrawal a depositor receives benefit ν with c.d.f. (p.d.f.) $F(\nu)$ $(f(\nu))$ over support $[\underline{\nu}, \bar{\nu}]$. This reflects various opportunities and needs that require cash. Withdrawal incurs a marginal cost of κ. Therefore, depositor i finds it optimal to withdraw the entire b_i if ν is large enough such that

$$1 + \nu - \kappa \geq q,$$

where the deposit price q equals the risk-adjusted present value of future payments and is thus exactly the opportunity cost of withdrawing.

In this setup, the mass of withdrawing depositors is given by:

$$\lambda(q) = 1 - F(q + \kappa - 1), \tag{21}$$

and the liquidity value per unit of deposits combines holding and expected withdrawing benefits, i.e.

$$L\,(B, q) = \mu(B) + \int_{q+\kappa-1}^{\bar{\nu}} (\nu - \kappa) dF(\nu). \tag{22}$$

Given law of motion for B, i.e. $B' = \Omega(R, B)$, and that for R, an individual bank solves

$$\begin{aligned} z + v^e(R, B, b) = z + \max_{b'} \Big\{ & R - \lambda(q(R, B, b'))b + q(R, B, b')\{b' - [1 - \lambda(q(R, B, b'))]b\} \\ & + \frac{1}{r}\mathbf{E}\left\{ \int_{-v^e(R', B', b')}^{\bar{z}} [v^e(R', B', b') + z'] d\Phi(z') \right\} \Big\}, \end{aligned} \tag{23}$$

given

$$q(R,B,b')b' = \frac{1}{r}\mathbf{E}\Bigg\{v^b(B',b',q(R',B',h_b(R',B',b'))) + \int_{-\bar{z}}^{-v^e(R',B',b')}[z'+v^e(R',B',b')-\xi b']d\Phi(z')\Bigg\},$$

where $v^b(B,b,q) = \{L(B,q)+\lambda(q)+[1-\lambda(q)]q\}b$; $h_b(R,B,b)$ solves (23); $\lambda(.)$ and $L(.)$ are given by (21) and (22).

An equilibrium of the laissez-faire economy requires that individual banks' optimal deposit issuance policy is consistent with law of motion for aggregate deposits B, i.e. $\Omega(R,B) = h_b(R,B,B)$.

4.1.2 Ramsey regulator

A Ramsey regulator solves

$$\max_{\{V_t^e(R^t),Q_t(R^t),B_{t+1}(R^t)\}_{t=0}^{\infty}} \mathbf{E}_0 \sum_{t=0}^{\infty} \frac{1}{r^t}\Big[R_t + L(B_t,Q_t) - \xi B_t \Phi(-V_t^e)\Big],$$

subject to for all $t \geq 0$

$$V_t^e = R_t - \lambda(Q_t)B_t + Q_t\{B_{t+1} - [1-\lambda(Q_t)]B_t\} + \frac{1}{r}\mathbf{E}_t\Big[\int_{-V_{t+1}^e}^{\bar{z}}(z+V_{t+1}^e)d\Phi(z)\Big],$$

$$Q_t B_{t+1} = \frac{1}{r}\mathbf{E}_t\Big[V_{t+1}^b + \int_{-\bar{z}}^{-V_{t+1}^e}(z+V_{t+1}^e - \xi B_{t+1})d\Phi(z)\Big],$$

and no-Ponzi and no-bubble conditions, where $V_t^b = \{L(B_t,Q_t)+\lambda(Q_t)+[1-\lambda(Q_t)]Q_t\}B_t$; $\lambda(.)$ and $L(.)$ are given by (21) and (22); R^t is the history of aggregate productivities up to period t.

4.1.3 Markov-perfect regulator

Given B and law of motion for R, a Markov-perfect regulator solves:

$$H(R,B) = \max_{B'}\ R + L\left(B, Q\left(R,B'\right)\right)B - \xi B \Phi\left(-V^e(R,B,B')\right) + \frac{1}{r}\mathbf{E}H(R',B'), \quad (24)$$

given

$$V^e(R,B,B') = R - \lambda(Q(R,B'))B + Q(R,B')\{B' - [1-\lambda(Q(R,B'))]B\}$$
$$+ \frac{1}{r}\mathbf{E}\left\{\int_{-V^e(R',B',h_B(R',B'))}^{\bar{z}} [z' + V^e(R',B',h_B(R',B'))]d\Phi(z')\right\}, \qquad (25)$$
$$Q(R,B')B' = \frac{1}{r}\mathbf{E}\bigg\{V^b(B',Q(R',h_B(R',B')))$$
$$+ \int_{-\bar{z}}^{-V^e(R',B',h_B(R',B'))} [z' + V^e(R',B',h_B(R',B')) - \xi B']d\Phi(z')\bigg\},$$

where $V^b(B,Q) = \{L(B,Q) + \lambda(Q) + Q[1-\lambda(Q)]\}B$; $h_B(R,B)$ solves (24); $\lambda(.)$ and $L(.)$ are given by (21) and (22).

4.2 Solution

For the Ramsey problem, we show the existence of a pseudo steady state in some aggregate quantities. Specifically, B_t, Q_t and V_t^e converge to a stationary point. However, Lagrange multipliers associated with equity and pricing constraints, even when multiplied by r^t to adjust for time discounting, keep growing at a speed under which the no-Ponzi and no-bubble conditions are satisfied. This is different from common models, i.e. consumption-saving models, where Lagrange multipliers becomes stationary after adjusted for time discounting, and is reminiscent of characterizations in the optimal taxation literature where convergence of multipliers cannot always be established (e.g. Straub and Werning, 2020; Chien and Wen, 2022; Bassetto and Cui, Forthcoming). While we prove Proposition 6 for our model with non-maturing deposits, our baseline model with fixed maturity exhibits the same property. To solve the Ramsey problem requires us to first substitute out all multipliers by hand.

Proposition 6 *The existence of a Ramsey steady state in which real variables B_t, V_t and Q_t stay constant does not imply constant Lagrange multipliers.*

Proof. See Appendix A.5. ■

The problems of the Markov-perfect regulator and laissez-faire banks (also the partial commitment regulators) are nontrivial to solve. Local approximations of such equations are challenging because generalized Euler equations include derivatives of policy functions which are not determined by the system of first-order conditions (Klein, Krusell and Rios-Rull, 2008). We build on Gomes, Jermann and Schmid (2016) and Dennis (2022) for a fully local method that is scalable and can solve the steady state with essentially no approximation error. Our approach can also handle the distinction between aggregate and individual state variables. To illustrate the main idea of the approach, consider the steady-state first-order condition for a laissez-faire bank in our baseline model with fixed maturity and aggregate productivity, i.e. Equation (13), which involves a pricing derivative given by:[16]

$$\frac{\partial q(b')}{\partial b'}b' + q(b') = \frac{1}{r}\Bigg\{\mu + [\lambda + (1-\lambda)q(h_b(b'))][1 - \xi b'\phi(-v^e(b')) - \Phi(-v^e(b'))] \\ - \xi\Phi(-v^e(b')) + (1-\lambda)b'\frac{\partial q(h)}{\partial h}|_{h=h_b(b')}\frac{\partial h_b\,(b')}{\partial b'}\Bigg\}.$$

For local solutions, policy function cannot be pinned down before solving for the steady state. Therefore, with the presence of $\frac{\partial h_b(b')}{\partial b'}$, the system of first-order conditions used for local solutions is short one equation. To fill the gap, we iterate over the steady state and local dynamics jointly. In particular, for a conjectured linear process for $\frac{\partial h_b(b')}{\partial b'}$, we solve for the model's steady state and then perturb it to the second order (for instance with Dynare). The computed dynamics allow us to update the conjecture for $\frac{\partial h_b(b')}{\partial b'}$. This process is repeated until convergence.

Our parametrization is as follows. A period is a year. The average profitability of bank assets is $R^* = 0.02$. The default loss is $\xi = 0.2$. The withdrawal cost is $\kappa = 0.1$. We assume that ν follows an exponential distribution, i.e. $f(\nu) = a\exp(-a\nu)$, with $a = 20$. These choices follow Jermann and Xiang (2023) who aim to approximately match simulated moments of the laissez-faire economy and obvious empirical counterparts. We differ in four parameters to produce a higher default risk, without which Ramsey solutions can feature steady states with zero default and less interesting local dynamics. For the zero-mean i.i.d. shocks to profitability, we set $\phi(z) = \iota_0 - \iota_1 z^2$. By imposing $\phi(\bar{z}) = 0$ and $\Phi(\bar{z}) = 1$, we can use $\bar{z}$ to pin down ι_0 and ι_1. We set $\bar{z} = 0.26$. We set the benefit of holding deposits as $\mu(B) = 0.1245 - 0.012 \times B$. Finally, we set the discount rate to $1/r = 0.9$.

[16] This is obtained by differentiating the left- and right-hand sides of (12) at the same time.

4.3 Steady states

Table 1 shows the deterministic steady states for laissez-faire, Ramsey- and Markov-perfect-regulated (MP) economies. We highlight two main findings. First, by comparing laissez-faire and two regulated economies on the left panel, one can see that with regulation the default rate is a lot lower while the amount of deposits is a lot higher. By addressing dilution, capital regulation can actually increase the steady-state amount of deposits B_{ss} that banks absorb. This is despite the fact that regulators internalize that a large amount of deposits leads to a low marginal value of holding them, i.e. $\partial\mu(B)/\partial B < 0$. In laissez-faire, banks' strong incentive to dilute ex post is punished heavily by a large credit spread at the issuance stage, making deposits very costly for banks. Capital regulation assures depositors that their money is safe to some extent and therefore facilitates borrowing. Even though steady states of regulated economies admit more deposits, default risks $\Phi(-V_{ss}^e)$ are much lower. This result highlights how the borrowing constraint is endogenously tightened up by banks' dilution incentive, which is in sharp contrast to models where bank deposits are insured and capital requirements reduce equilibrium debt.[17]

Table 1: **Steady states of laissez-faire and regulated economies**

Parameters: $r = 1/0.9, \xi = 0.2, \kappa = 0.1, a = 20, \mu = 0.1245 - 0.012 \times B, R^* = 0.02, \rho_R = 0, \sigma_R = 0, \bar{z} = 0.26$. For the fixed-maturity model with $\lambda = 0.3439$, we adjust $\bar{z} = 0.121$ and $\mu = 0.098-0.012\times B$ for comparability between laissez-faire economies.

	Endogenous maturity			Fixed maturity		
Moments	Laissez-faire	Ramsey	MP	Laissez-faire	Ramsey	MP
B_{ss}	0.5165	1.1269	0.8166	0.5160	0.5633	0.5622
V_{ss}^e	0.1534	0.2112	0.2207	0.0897	0.1119	0.1127
$\Phi(-V_{ss}^e)$	0.1089	0.0248	0.0163	0.0457	0.0041	0.0034
λ_{ss}	0.3439	0.1213	0.0707	0.3439	0.3439	0.3439
L_{ss}	0.1195	0.1177	0.1205	0.0918	0.0912	0.0913
H_{ss}	0.7046	1.4706	1.1577	0.6266	0.7093	0.7092
$1 - B_{ss}/H_{ss}$	0.2669	0.2337	0.2946	0.1764	0.2058	0.2073

[17] That the amount of deposits in the laissez-faire is smaller than in the regulated economies does not imply non-binding capital requirements. For instance, in the steady states of Markov-perfect regulated economies, both under endogenous- and fixed-maturity, we have verified that bank equity value function $V^e(R, B, B')$ is locally increasing in B' when evaluated at the point $(R, B, B') = (R^*, B_{ss}, B_{ss})$. This means that banks themselves would like to absorb more deposits than the B_{ss} chosen by a Markov-perfect regulator.

Second, by comparing between two regulated economies on the left panel, we find that regulatory commitment can lead to a larger amount of deposits and a higher default risk. Naturally, commitment implies better outcomes—for instance, the total value in steady state H_{ss} is higher in the Ramsey-regulated economy. However, we do not find bank leverage B_{ss}/H_{ss} or default risk to be lower. The Ramsey regulator's ability to commit brings a better tradeoff between liquidity benefits and default costs, who ends up issuing more deposits to create liquidity while admitting more defaults. In contrast, to issue more deposits forces the Markov-perfect regulator to bear a much larger amount of default risk and is not optimal. Interestingly, we find that the steady state leverage chosen by the Ramsey regulator can be even higher than that in laissez-faire. This highlights the importance of properly accounting for regulatory commitment before making model-based policy recommendations regarding the appropriate level of capital requirements.

In addition to these two main results, it is worth noting that the endogeneity of deposit withdrawals can significantly amplify the value of regulatory commitment. We solve on the right panel our baseline model in Section 2 with fixed maturity and no net benefit of withdrawing. We in this case fix $\lambda = 0.3439$, and then re-adjust $\mu(B) = 0.098 - 0.012 \times B$ and $\bar{z} = 0.121$ so that laissez-faire economies with and without endogenous withdrawals have a similar amount of deposits in steady states. We find that with endogenous withdrawals, commitment can produce large differences in steady state levels of deposits B_{ss} and total value H_{ss}.[18] This is because endogenous withdrawals imply that future bank leverage will affect not only the current value of unmatured deposits as in our baseline setup, but also the amount that ends up getting matured today, i.e. how many depositors end up withdrawing. This additional channel can amplify the negative effect of inefficient leverage taking resulting from lack of commitment. In particular, withdrawals affect banks' default incentive and depositors' liquidity benefits by (24), and being able to commit to future leverage allows the Ramsey regulator to better manage the impact of today's withdrawals. Our result suggests that this further widens the difference between Ramsey and Markov-perfect regulators regarding their optimal policies and how much value can be created.

[18] In an alternative recalibration with $\mu(B) = 0.07 - 0.012 \times B$ and $\bar{z} = 0.15$, laissez-faire economies with and without endogenous withdrawals have similar steady-state leverage ratios B_{ss}/H_{ss} and default probabilities $\Phi(-V^e_{ss})$. Our results are similar.

4.4 Responses to aggregate shocks

This section shows the dynamics of regulated and laissez-faire economies in response to shocks to aggregate productivity R. This experiment is informative about the optimal setting of a countercyclical capital buffer (CCyB). It also connects to our empirical tests in Section 5.

Figure 1 reports the impulse responses to a negative i.i.d. R shock at $t = 10$, which represents a recession caused by, for example, a housing crisis or a pandemic that lasts for one year. Upon the shock, bank equity values fall and therefore banks default more. By allowing banks to issue more deposits, both Ramsey and Markov-perfect regulators inflate the equity value and incentivize banks to default less.

Importantly, there is a clear difference in terms of policy persistence between the two regulators. Right upon the shock, the Markov-perfect regulator aggressively increases deposits for $t = 11$. Even though an immediate deleveraging at $t = 12$ is costly because this requires banks to inject a large amount of equity to retire these deposits who are therefore very likely to default, the deleveraging still unfolds relatively rapidly. In comparison, the Ramsey regulator increases deposits for $t = 11$ in a milder way, but importantly commits to extend the increase for a longer time even though it becomes value destroying after productivity has reverted back to its long-run level. This allows Ramsey to better resolve defaults at $t = 10$. Panels (1c) and (1d) display the equity ratios $1 - B/H$ in two regulated economies and the difference between them (Ramsey-MP, i.e. Ramsey minus Markov-perfect). Relative to the Markov-perfect regulator, the Ramsey regulator keeps the equity ratio low for a longer period of time post the shock.

Figure 2 considers a typical business cycle shock, i.e. a small but persistent drop in asset productivity R, specifically with $\rho_R = 0.9$ and $\sigma_R = 0.01$. For both regulators, aggregate bank deposits shrink drastically to reduce the exposure of banks to the long-lasting increase in default risk. By (2c) and (2d), the impact of commitment echoes that in the i.i.d. shock case—that is, relative to the Markov-perfect regulator, the Ramsey regulator adopts a low equity ratio for quite a period of time. Overall, our result lends support to policy designs that bound the ability of a regulator to quickly revert capital buffers back to a stringent level after they get reduced, with the EU Capital Requirements Directive as a prominent example.

Figure 3 plots the responses of the laissez-faire economy to negative productivity shocks and compares them with those of the Markov-perfect regulated economy (MP-LF represents

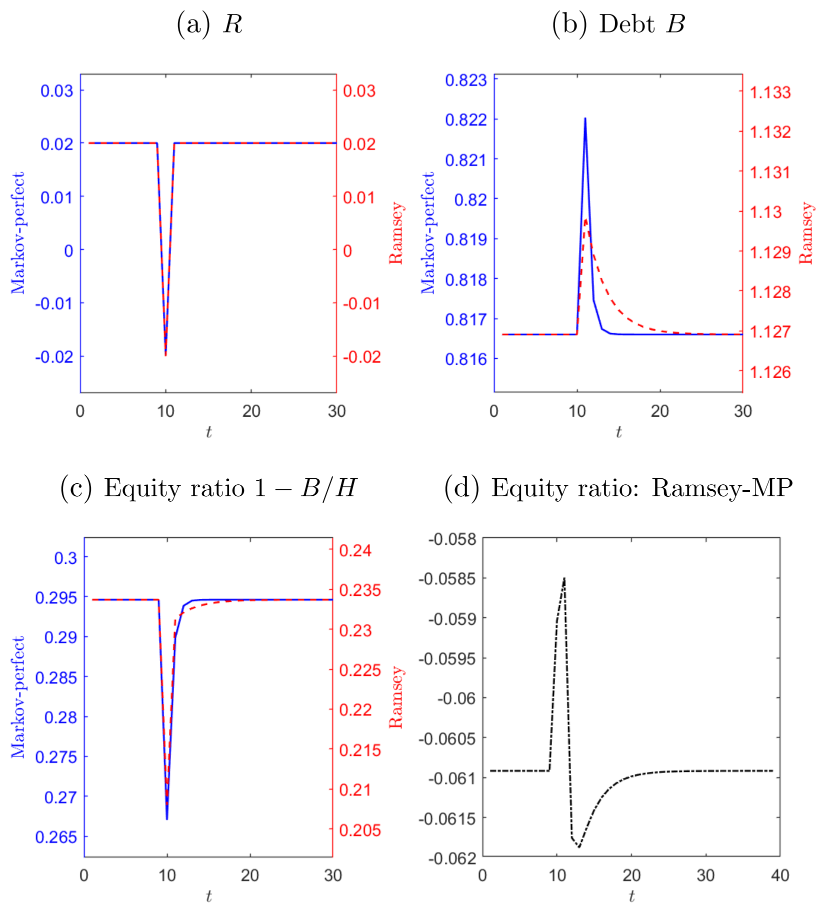

Figure 1: Regulator's commitment and impulse responses to i.i.d. R shocks. *Notes*: $\rho_R = 0, \sigma_R = 0.04$, and the other parameters follow Table 1. Ramsey-MP represents Ramsey minus Markov-perfect.

Markov-perfect minus laissez-faire). Panels (3a)-(3c) show the i.i.d. shock case. When shocks are i.i.d., banks themselves do not adjust the amount of deposits, which implies that post-shock periods do not observe a lower equity ratio. This is because equity value is already maximized under banks' own choice for b', and therefore pushing it up further does not help reduce default probability. In contrast, the regulator restricts deposit issuance in steady state to address dilution, and has the room to allow more deposits to temporarily increase equity value when a negative shock hits. Panel (3c) shows that capital regulation stringency, the difference between the required capital ratio and banks' own optimal choice, falls right following the shock. Panels (3d)-(3f) show the persistent shock case. Similar to the i.i.d.

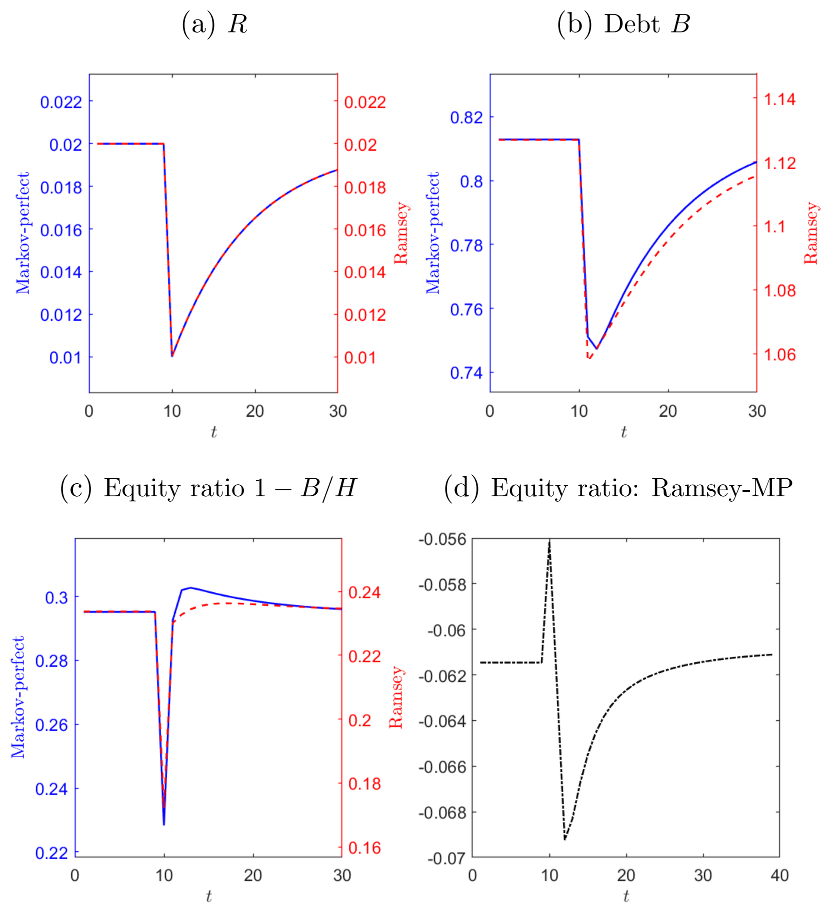

Figure 2: Regulator's commitment and impulse responses to persistent R shocks. *Notes*: $\rho_R = 0.9, \sigma_R = 0.01$, and the other parameters follow Table 1. Ramsey-MP represents Ramsey minus Markov-perfect.

case, capital regulation stringency reduces post the shock.

5 Empirical analysis

Our theory suggests that regulatory commitment plays an important role for bank capital regulation. Cross-country data on the evolution of capital regulation stringency around the 2008 global financial crisis allow us to test our model implications, particularly the dynamic responses to a negative shock studied in Section 4.4. We present two novel facts that are

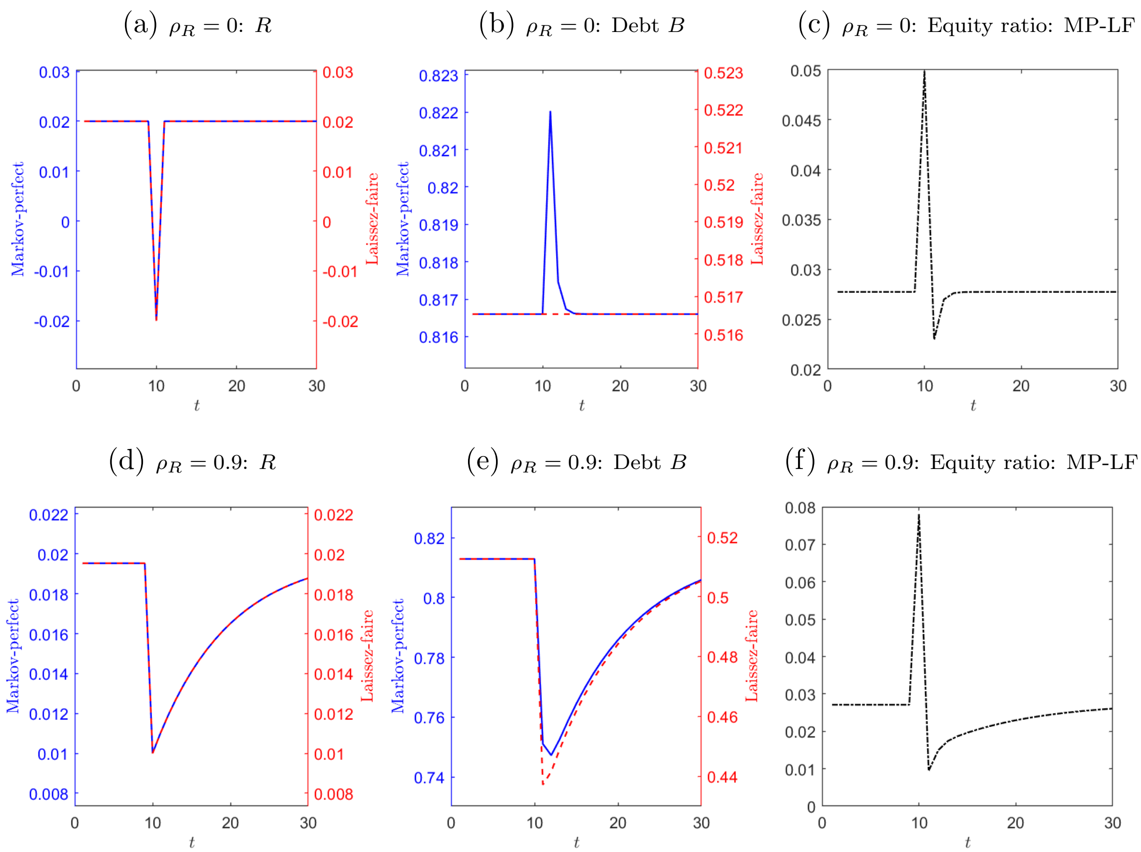

Figure 3: Laissez-faire impulse responses to R shocks. *Notes*: $\rho_R = 0, \sigma_R = 0.04$ in the upper panel and $\rho_R = 0.9, \sigma_R = 0.01$ in the lower panel. The other parameters follow Table 1. MP-LF represents Markov-perfect minus laissez-faire.

consistent with our results. First, a GDP contraction during crisis implies a lower post-crisis stringency for governments that more likely have a welfare-maximizing objective. Second, among governments who are highly likely maximizing welfare, a GDP contraction during crisis implies a lower post-crisis stringency for those exhibiting more commitment. The first fact corresponds to our result that regulated economies loosen capital requirements post a negative shock (Panels (3c) and (3f)), and the second fact corresponds to our result that a Ramsey regulator extends such leniency for longer compared to a Markov-perfect regulator (Panels (1d) and (2d)).

5.1 Data and variables

Our data are from several sources. Country-level economic variables that we use as controls are from the Penn World Table and the IMF Global Debt Database. Capital stringency index is from Barth, Caprio and Levine (2013), who collaborated with the World Bank and conducted surveys about bank regulation in 180 countries in 4 waves, i.e. 1999, 2002, 2006 and 2011. We use their scaled *Initial Stringency Index* that captures the minimum capital adequacy ratio and their scaled *Overall Stringency Index* that describes the risk weighting of bank assets. A higher value indicates greater stringency.

We use two key political economy measures that describe the functioning of governments. The first has to do with the total-value-maximizing objective of the government and the second has to do with its commitment power. For the first, we use the *Regulatory Quality Index* from the World Bank's World Governance Indicators (WGI) project, which describes "the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development" based on questions about whether the government has created an efficient business environment.[19] For robustness, we also exploit the *Government Effectiveness Index* from the WGI, which describes whether the government has provided high quality public goods. For the second, we use the Factor 1.5 *Rule of Law Index* from the widely popular World Justice Project (WJP). It describes how government powers are subject to non-governmental checks based on questions about whether independent media, civil society organizations, political parties, and individuals are free to act. We consider a government with a higher *Rule of Law Index* to have more commitment, for whom breaking past promises is not easy.[20]

5.2 Empirical evidence

Section 5.2.1 presents fact one that pertains to the regulatory objective and corresponds to our comparison between laissez-faire and regulated economies. Section 5.2.2 presents

[19] The underlying questions cover a wide range of topics beyond just financial regulation, which alleviates to some extent the reverse causality issue.

[20] While our post-crisis capital regulation stringency index is available only in 2011, the WJP dataset starts at 2012. As the regulatory environment of a country is recognized to be quite stable over a short window, we use *Rule of Law* in either 2012 or the closest later-reported value. In Appendix D.1, we use other rule of law measures from the WJP dataset as well as the one from the WGI dataset, for the latter of which we do have observations for the year 2011. Our results are similar.

fact two that relates to regulatory commitment and corresponds to our comparison within regulated economies. Section 5.2.3 connects these results with anecdotal evidence.

5.2.1 Regulatory objective and post-crisis capital requirements

Our model suggests that both Ramsey and Markov-perfect regulators would reduce capital regulation stringency after a negative shock. We therefore hypothesize that given pre-crisis regulation stringency, a GDP contraction during crisis leads to less stringent post-crisis capital requirements in countries that are more likely to have a welfare-maximizing government. We run the following regression:

$$\begin{aligned} Cap_{i,2011} = \beta_0 + \beta_1 Cap_{i,2006} + \beta_2 GDPdrop_i + \beta_3 Obj_{i,2011} \\ + \beta_4 GDPdrop_i \times Obj_{i,2011} + \sum_k \beta_k Controls^k_{i,2011} + \epsilon_i. \end{aligned} \tag{26}$$

Our dependent variable $Cap_{i,t}$ is the *Capital Regulation Index* of country i in year t, which is defined as the sum of *Initial Stringency Index* and *Overall Stringency Index* following Barth, Caprio and Levine (2013).[21] Our main independent variable $Obj_{i,2011}$ is either the *Regulation Quality Index* (*Quality*) or the *Government Effectiveness Index* (*Effectvns*). Our measure of GDP contraction is $GDPdrop_i = 100 \times \left(1 - \frac{\min_{t\in[2008,2010]} GDP_{i,t}}{GDP_{i,2007}}\right)$, i.e. the extent to which country i's real GDP between 2008 and 2010 had ever dropped below its 2007 value.[22] We control for the pre-crisis stringency $Cap_{i,2006}$ and the following variables in 2011: logarithm of real GDP, logarithm of population, central government debt to GDP ratio, and a dummy for membership in Basel committee. It is important to notice that some countries were still in crisis in 2011, such as Greece and Jamaica. Our theory suggests that their regulatory policy making in 2011 shall be in nature different from those who had fully recovered. Therefore, we restrict our sample to countries whose real GDP in 2011 exceeded its 2007 level.

Table 2 shows our results. In columns (1) and (2), we use the *Regulation Quality Index*

[21] Since capital regulation paradigm prior to 2008 was quite stable, for countries with missing overall or initial stringency indices in 2006, we use their most recent reported values. In the raw data, average *Capital Regulation Index* in 1999, 2002, and 2006 was respectively 5.8, 6.0, and 5.8, whereas that in 2011 was 7.3.

[22] This is similar to the peak-to-trough crisis severity measure of Reinhart and Rogoff (2009). In Appendix D.2, we consider a dummy variable that is equal to 1 for country i if $\min_{t\in[2008,2010]} GDP_{i,t} < GDP_{i,2007}$ and to 0 otherwise. Our results are robust. In D.2, we also conduct a placebo test using the behavior of GDP prior to the 2008 crisis.

Table 2: **Regulatory objective and post-crisis capital requirements**

Dependent variable is Cap_{2011}. For independent variable Obj, columns (1) and (2) use the *Regulation Quality Index* and columns (3) and (4) use the *Government Effectiveness Index*. Control variables include log real GDP, log population, central government debt to GDP ratio, and a dummy for membership in Basel committee, all at 2011. Standard errors are in parentheses. ***/**/* denotes 99%/95%/90% significance.

	Obj=Quality		*Obj=Effectvns*	
	(1)	(2)	(3)	(4)
Obj × *GDPdrop*	-0.085*	-0.107**	-0.088*	-0.092*
	(0.047)	(0.054)	(0.048)	(0.054)
GDPdrop	0.000	-0.015	0.001	-0.014
	(0.040)	(0.044)	(0.040)	(0.044)
Obj	-0.273	-0.529*	-0.257	-0.568*
	(0.206)	(0.310)	(0.199)	(0.324)
Cap_{2006}	0.199**	0.228**	0.198**	0.216**
	(0.092)	(0.101)	(0.092)	(0.100)
Controls	No	Yes	No	Yes
R^2	0.083	0.126	0.083	0.120
Obs	103	92	103	92

as our independent variable. Our key interest is in β_4, which is estimated to be negative and statistically significant. This implies that for a given magnitude of GDP contraction during crisis, a government that is more likely welfare-maximizing decided on post-crisis capital requirements by showing more leniency. This is consistent with our theoretical result that regulators loosen capital requirements upon a negative shock. Adding control variables does not alter our point estimates in a significant way. In columns (3) and (4), we use the *Government Effectiveness Index* as our measure of government's objective of welfare maximization, and our results are robust.

5.2.2 Regulatory commitment and post-crisis capital requirements

Now we consider the role of regulatory commitment. Our model suggests that the Ramsey regulator would like to loosen capital requirements for longer post crisis than a Markov-perfect regulator. We sort countries based on regulatory objective $Obj_{i,2011}$ into three equal subsamples, and then run the following regression in different subsamples:

$$\begin{aligned} Cap_{i,2011} = \beta_0 + \beta_1 Cap_{i,2006} + \beta_2 GDPdrop_i + \beta_3 Comm_i \\ + \beta_4 GDPdrop_i \times Comm_i + \sum_k \beta_k Controls^k_{i,2011} + \epsilon_i, \end{aligned} \tag{27}$$

where $Comm_i$ is the *Rule of Law Index* that proxies for regulatory commitment. Our key interest is in β_4 for the high-Obj sample, which includes countries that are very likely to have a welfare-maximizing regulator. Since the size of each subsample drops to be around 30, we include only logarithm of real GDP and $Obj_{i,2011}$ itself as our controls.

Table 3 reports our results. Panel A sorts countries based on the *Regulation Quality Index* while Panel B sorts based on the *Government Effectiveness Index*. In columns (1) and (2), we estimate β_4 to be negative and statistically significant. This suggests that, for a given magnitude of GDP contraction during crisis, a welfare-maximizing government with more commitment decided on post-crisis capital requirements by showing more leniency. This is consistent with our comparison between Ramsey and Markov-perfect regulators in the model. Whether to add controls or not does not vary point estimates much. From columns (3) to (6), as we expand our sample to also include countries with medium- and low-Obj, the effect of commitment vanishes. In other words, commitment is less relevant for governments that are likely not maximizing social welfare at all.

5.2.3 Interpreting the empirical results

The dataset on capital regulation stringency ends at 2011, before Basel III's new rules got widely implemented. Therefore, changes in regulation stringency did not correspond to how governments vary capital buffers across time under the Basel III framework. Instead, in the examined period around the crisis, governments made a series of decisions, regarding for instance how to better getting out of the crisis or how quickly to embrace the Basel III, that could affect capital stringency, and they had quite a lot of discretion over these decisions. This allows us to test our theory.

During the 2008 crisis, to avoid massive bank defaults, many governments purchased preferred bank stocks at a cheap price, including for example the US Troubled Asset Relief

Table 3: **Regulatory commitment and post-crisis capital requirements**

Dependent variable is Cap_{2011}. Independent variable *Comm* is the Factor 1.5 WJP *Rule of Law Index*. Panel A sorts countries into three subsamples (*High, Medium, Low*) based on $Quality_{i,2011}$ and panel B sorts countries based on $Effectvns_{i,2011}$. Control variables include log real GDP in 2011 and the regulatory objective measure in 2011, i.e. $Quality_{i,2011}$ in panel A and $Effectvns_{i,2011}$ in panel B. Standard errors are in parentheses. ***/**/* denotes 99%/95%/90% significance.

	High		*High+Medium*		*High+Medium+Low*	
	(1)	(2)	(3)	(4)	(5)	(6)
			Panel A. Sort by *Quality*			
Comm × *GDPdrop*	-2.001**	-1.982**	-0.001	-0.021	-0.185	-0.184
	(0.788)	(0.785)	(0.381)	(0.398)	(0.219)	(0.228)
GDPdrop	1.406**	1.440**	-0.054	-0.047	0.079	0.073
	(0.576)	(0.572)	(0.262)	(0.266)	(0.134)	(0.135)
Comm	-1.896	-1.696	-1.944	-1.703	-1.654	-1.351
	(2.649)	(2.692)	(1.824)	(2.136)	(1.186)	(1.622)
Cap_{2006}	0.544***	0.537**	0.261*	0.281*	0.220**	0.222**
	(0.165)	(0.166)	(0.141)	(0.147)	(0.103)	(0.104)
Controls	No	Yes	No	Yes	No	Yes
R^2	0.409	0.470	0.106	0.122	0.088	0.110
Obs	28	28	58	58	86	86
			Panel B. Sort by *Effectvns*			
Comm × *GDPdrop*	-2.219***	-1.802**	0.022	0.037	-0.185	-0.206
	(0.707)	(0.815)	(0.396)	(0.411)	(0.219)	(0.230)
GDPdrop	1.548***	1.270**	-0.081	-0.087	0.079	0.078
	(0.507)	(0.577)	(0.277)	(0.280)	(0.134)	(0.135)
Comm	0.921	1.178	-2.020	-1.727	-1.654	-1.792
	(1.946)	(2.016)	(1.823)	(1.965)	(1.186)	(1.472)
Cap_{2006}	0.536***	0.537***	0.316**	0.324**	0.220**	0.228**
	(0.173)	(0.177)	(0.140)	(0.141)	(0.103)	(0.104)
Controls	No	Yes	No	Yes	No	Yes
R^2	0.465	0.497	0.137	0.163	0.088	0.108
Obs	26	26	55	55	86	86

Program (TARP) and the UK bank rescue package. This type of regulatory actions resembles a temporary relaxation of capital requirements in our model as they boost equity value at the cost of other parties. This cost can be viewed as a too-big-to-fail cost from exacerbating the moral hazard problem of bankers or simply a fiscal cost. As share buybacks typically involve frictions[23], one interpretation of our first finding is that well-functioning governments are more likely to adopt this type of policies.

The planning of share buybacks involves government commitment power. For instance, in exchange for the TARP investment, banks have to give the US Treasury a 5% annual dividend before 2013 and 9% thereafter. Such a design was to incentivize banks to buyback shares in 5 years. Clearly, a government without any commitment could have reneged and pushed banks to buy back more quickly. This was clearly of interest for some at the end of 2009 given a strong US economy together with a heated Wall-Street-vs-Main-Street tension at that point.[24] The UK government also designed a long window to sell back the stocks it purchased through the bank rescue package. For instance, the UK government has self-imposed a 2026 deadline to fully privatize the NatWest, formerly known as the Royal Bank of Scotland, which clearly involves commitment.

Besides deciding on how to deal with bank shares bought in crisis, countries, even including Basel members, have the discretion whether to accelerate the adoption of Basel III's stringent standards (Basel Committee on Banking Supervision, 2020). Relatedly, Gropp et al. (2024) provide evidence that European countries allowed their domestic banks to inflate "on paper" their level of regulatory capital to accommodate the 2011 Capital Exercise conducted by the European Banking Authority.[25] Countries might have the incentive to slow down the transition process and lend continuous support to banks if they have made promises, private or public, during the crisis to prevent defaults. Overall, while the empirical evidence we present in this section is non-causal and suggestive, it is consistent with our key theoretical insight that regulators with commitment would like to extend the help they lend to banks for longer, as a more effective way to resolve a crisis.

[23] According S&P Global, two banks and two credit unions were still participating in TARP as of August, 2020: https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/only-4-financial-institutions-still-left-under-tarp-after-carver-exit-60078068.

[24] See the debate about whether to renew TARP at the end of 2009 during a congressional hearing: https://www.govinfo.gov/content/pkg/CHRG-111shrg53177/html/CHRG-111shrg53177.htm.

[25] Maddaloni and Scopelliti (2019) show that prior to the crisis, prudential regulation in the EU was implemented non-uniformly across countries.

6 Conclusions

In this paper, we provide the first analysis of the time inconsistency problem of bank capital regulation. When financed with long-term defaultable deposits, banks in laissez-faire have an incentive to take an excessive leverage that dilutes the value of legacy depositors. Capital regulators correct the strong dilution incentive of banks but preserve some dilution as such leniency is valuable for reducing bank defaults. A regulator with commitment can use promises to future leniency—allowing an excessive leverage that implies a suboptimally high level of dilution tomorrow—to persuade banks to not default today. We show that commitment has long-run effects that are significant. Additionally, upon a negative shock, we show that regulators find a temporary relaxation of capital requirements beneficial, and one with commitment uses promises to extend such leniency into a longer period of time. Our theory is consistent with cross-country changes in capital regulation stringency around the 2008 global financial crisis and echoes policy makers' preliminary attempts to develop a systematic framework that limits the discretion of capital regulators.

We have intentionally kept our model simple so that we can illustrate the time inconsistency problem of capital regulation with transparency. Even though we have incorporated non-maturing deposits to reflect a salient feature of bank debt relative to typical non-financial corporate debt, there are other features worth incorporating from a quantitative standpoint. For instance, while we have been focusing on the standard agency conflict between equity holders and depositors of a bank, i.e. a dilution problem, the model can be easily extended to allow distortions from deposit insurance. The existence of insured deposits will not change the key insights of the paper but can be valuable for making precise quantitative prescriptions. Furthermore, it is interesting to consider a full-blown general equilibrium model with firm production, capital accumulation, and household preferences. We leave these to future research.

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Appendix

A Proofs

A.1 Proposition 1

The Lagrangian for our sequential Ramsey regulator in Section 2.2.1 is:

$$\max_{\{V_t^e, Q_t, B_{t+1}, \gamma_t, \zeta_t\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \frac{1}{r^t} \Bigg\{ R + \mu(B_t)B_t - \xi B_t \Phi(-V_t^e) \\ + \gamma_t \Bigg\{ R - \lambda B_t + Q_t[B_{t+1} - (1-\lambda)B_t] \\ + \frac{1}{r}\left[\int_{-V_{t+1}^e}^{\bar{z}} (z + V_{t+1}^e) d\Phi(z) \right] - V_t^e \Bigg\} \\ + \zeta_t \Bigg\{ \frac{1}{r} \Bigg[\left[\mu(B_{t+1}) + \lambda + (1-\lambda)Q_{t+1}\right] B_{t+1} \\ + \int_{-\bar{z}}^{-V_{t+1}^e} (z + V_{t+1}^e - \xi B_{t+1}) d\Phi(z) \Bigg] - Q_t B_{t+1} \Bigg\} \Bigg\},$$

where γ_t and ζ_t are two Lagrange multipliers; B_0 is predetermined.

An interior equilibrium allocation can be solved through three sets of first-order conditions (with respect to B_{t+1}, V_t^e, Q_t) and two sets of constraints. First-order conditions at time $t > 0$ are given by:

$$\frac{1}{r}\{\mu_{t+1} + B_{t+1}\mu_{t+1}^B - \xi\Phi(-V_{t+1}^e) - \gamma_{t+1}[\lambda + Q_{t+1}(1-\lambda)]\} + \gamma_t Q_t \\ + \zeta_t \left\{ \frac{1}{r}[\lambda + \mu_{t+1} + B_{t+1}\mu_{t+1}^B + (1-\lambda)Q_{t+1} - \xi\Phi(-V_t^e)] - Q_t \right\} = 0,$$

$$\gamma_t[B_{t+1} - (1-\lambda)B_t] - \zeta_t B_{t+1} + \zeta_{t-1}(1-\lambda)B_t = 0,$$

$$\xi\phi(-V_t^e)B_t - \gamma_t + \gamma_{t-1}[1 - \Phi(-V_t^e)] + \zeta_{t-1}[\Phi(-V_t^e) + \xi\phi(-V_t^e)B_t] = 0,$$

where μ^B represents the derivative of $\mu(B_t)$ with respect to B_t.

Meanwhile, first-order conditions at $t = 0$ are:

$$\frac{1}{r}\{\mu_{t+1} + B_{t+1}\mu^B_{t+1} - \xi\Phi(-V^e_{t+1}) - \gamma_{t+1}[\lambda + Q_{t+1}(1-\lambda)]\} + \gamma_t Q_t$$
$$+ \zeta_t \left\{\frac{1}{r}[\lambda + \mu_{t+1} + B_{t+1}\mu^B_{t+1} + (1-\lambda)Q_{t+1} - \xi\Phi(-V^e_t)] - Q_t\right\} = 0,$$
$$\gamma_t[B_{t+1} - (1-\lambda)B_t] - \zeta_t B_{t+1} = 0,$$
$$\xi\phi(-V^e_t)B_t - \gamma_t = 0.$$

Now consider the first-order conditions for the continuation problem in Proposition 1. They are given by:

$$\frac{1}{r}\left\{\mu' + \mu^{B\prime}B' - \xi\Phi(-V^{e\prime}) - \gamma'[\lambda + Q'(1-\lambda)]\right\} + \gamma Q$$
$$+ \zeta\left\{\frac{1}{r}\left[\lambda + \mu' + \mu^{B\prime}B' + (1-\lambda)Q' - \xi\Phi(-V^{e\prime})\right] - Q\right\} = 0,$$
$$\gamma'[B'' - (1-\lambda)B'] - \zeta' B'' + \zeta\,(1-\lambda)\,B' = 0,$$
$$\xi B'\phi(-V^{e\prime}) - \gamma' + \gamma[1 - \Phi(-V^{e\prime})] + \zeta\left[\Phi(-V^{e\prime}) + \xi B'\phi(-V^{e\prime})\right] = 0,$$

where γ and ζ are multipliers associated with promise keeping constraints on equity value and deposit price, respectively.

Two additional conditions that pin down Q_0 and V^e_0 in the initial problem are:

$$\gamma\,[B' - (1-\lambda)B] - \zeta B' = 0,$$
$$\xi\phi(-V^e)B - \gamma = 0.$$

One can see that these two sets of first-order conditions are identical. Together with identical constraints on bank equity values and deposit prices, they imply identical interior allocations.

A.2 Proposition 3

Define the objective of a Markov-perfect regulator as $\tilde{H}(B, B') \equiv R + \mu(B)B - \xi B\Phi(-V^e(B, B')) + \frac{1}{r}H(B')$ where value and pricing functions are given by

$$V^e(B, B') = R - \lambda B + Q(B')[B' - (1-\lambda)B] + \frac{1}{r}\left\{\int_{-V^e(B', h_B(B'))}^{\bar{z}} [z' + V^e(B', h_B(B'))]d\Phi(z')\right\}, \quad (28)$$

and

$$Q(B')B' = \frac{1}{r}\left\{[\mu(B') + \lambda + Q(h_B(B'))(1-\lambda)]B' + \int_{\underline{z}}^{-V^e(B', h_B(B'))} [z' + V^e(B', h_B(B')) - \xi B']\, d\Phi(z')\right\}. \quad (29)$$

Denote steady-state values under a Markov-perfect regulator with subscript ss. The first-order condition in steady state implies:

$$\frac{\partial \tilde{H}(B, B')}{\partial B'}|_{B=B'=B_{ss}} = 0.$$

Interior solution implies that deposits $B_{ss} > 0$ and default probability $\Phi_{ss} \in (0, 1)$.

We consider a regulator who chooses B' and B'' today at time t and follows the optimal policy of a Markov-perfect regulator beyond $t+2$. Our goal is to show that if conditions (i) and (ii) are satisfied, the objective of this regulator is strictly increasing in B'' when evaluated at the point where $B = B' = B'' = B_{ss}$. This makes a one-shot deviation to $B'' > B_{ss}$ profitable. This regulator's problem is given by:

$$\max_{B', B''} R + \mu(B)B - \xi B\Phi(-\tilde{V}^e(B, B', B'')) + \frac{1}{r}\tilde{H}(B', B'') \quad (30)$$

where

$$\tilde{V}^e(B, B', B'') = R - \lambda B + \tilde{Q}(B', B'')[B' - (1-\lambda)B] + \frac{1}{r}\left\{\int_{-V^e(B', B'')}^{\bar{z}} [z' + V^e(B', B'')]\, d\Phi(z')\right\}, \quad (31)$$

and

$$\tilde{Q}\left(B', B''\right) B' = \frac{1}{r}\left\{[\mu\left(B'\right) + \lambda + Q\left(B''\right)(1-\lambda)]B' + \int_{\bar{z}}^{-V^e(B',B'')} \left[z' + V^e\left(B', B''\right) - \xi B'\right] d\Phi(z')\right\}. \tag{32}$$

Combine (28) and (29), and then utilize (15). We can show:

$$V^e(B', B'') - \xi B'\Phi(-V^e(B', B'')) + V^b(B', Q(B'')) = \tilde{H}(B', B''). \tag{33}$$

where $V^b(B, Q) = [\mu(B) + \lambda + Q(1-\lambda)]B$. After plugging (32) into (31) and then using (33), we have:

$$\tilde{V}^e\left(B, B', B''\right) = R - \lambda B - (1-\lambda)B\tilde{Q}\left(B', B''\right) + \frac{1}{r}\tilde{H}(B', B'').$$

Differentiate the objective in (30) with respect to B''. Since $\frac{\partial \tilde{H}(B',B'')}{\partial B''}|_{B'=B''=B_{ss}} = 0$, the derivative at $B = B' = B'' = B_{ss}$ is given by:

$$-\xi B_{ss}\phi_{ss}(1-\lambda)B_{ss}\frac{\partial \tilde{Q}(B', B'')}{\partial B''}|_{B'=B''=B_{ss}}. \tag{34}$$

Given condition (ii), i.e. $\lambda < 1$, to show that (34) is strictly positive, it is sufficient to show that $\frac{\partial \tilde{Q}(B',B'')}{\partial B''}|_{B'=B''=B_{ss}} < 0$.

Using (33), we can rewrite (32) into:

$$\tilde{Q}\left(B', B''\right) B' = \frac{1}{r}\left\{\tilde{H}(B', B'') - \int_{-V^e(B',B'')}^{\bar{z}} \left[z' + V^e\left(B', B''\right)\right] d\Phi(z')\right\}.$$

Differentiate it with respect to B'' and then evaluate at steady state:

$$\frac{\partial \tilde{Q}(B', B'')}{\partial B''}|_{B'=B''=B_{ss}} = -\frac{1}{r}(1-\Phi_{ss})\frac{1}{B_{ss}}\frac{\partial V^e(B', B'')}{\partial B''}|_{B'=B''=B_{ss}}.$$

Here we again have utilized that $\frac{\partial \tilde{H}(B',B'')}{\partial B''}|_{B'=B''=B_{ss}} = 0$. To sign this expression, differentiate (33) with respect to B'' and then evaluate at steady state:

$$\frac{\partial V^e(B',B'')}{\partial B''}|_{B'=B''=B_{ss}}(1+\xi B_{ss}\phi_{ss}) + (1-\lambda)B_{ss}\frac{\partial Q(B'')}{\partial B''}|_{B''=B_{ss}} = \frac{\partial \tilde{H}(B',B'')}{\partial B''}|_{B'=B''=B_{ss}} = 0.$$

Condition (i), i.e. $\frac{\partial Q(B')}{\partial B'}|_{B'=B_{ss}} < 0$, and (ii), i.e. $\lambda < 1$, together imply that $\frac{\partial V^e(B',B'')}{\partial B''}|_{B'=B''=B_{ss}} > 0$. This implies $\frac{\partial \tilde{Q}(B',B'')}{\partial B''}|_{B'=B''=B_{ss}} < 0$.

A.3 Proposition 4

Define the objective of a laissez-faire bank as $\tilde{v}^e(b,b') \equiv R - \lambda b + q(b')[b' - (1-\lambda)b] + \frac{1}{r}\int_{-v^e(b')}^{\bar{z}}[z' + v^e(b')]d\Phi(z')$ where pricing function is given by

$$q(b')b' = \frac{1}{r}\left\{[\mu(B) + \lambda + (1-\lambda)q(h_b(b'))]b' + \int_{-\bar{z}}^{-v^e(b')}[z' + v^e(b') - \xi b']d\Phi(z')\right\}, \tag{35}$$

recognizing the fact that aggregate B is constant.

Denote steady state values in laissez-faire with subscript ss. The first-order condition in steady state implies:

$$\frac{\partial \tilde{v}^e(b,b')}{\partial b'}|_{b=b'=b_{ss}} = 0.$$

Interior solution implies that deposits $b_{ss} > 0$ and default probability $\Phi_{ss} \in (0,1)$.

We consider a bank who chooses b' and b'' today at time t and follows the optimal policy of a laissez-faire bank without commitment beyond $t+2$. Our goal is to show that if conditions (i) and (ii) are satisfied, the objective of this bank is strictly decreasing in b'' when evaluated at the point where $b = b' = b'' = b_{ss}$. This makes a one-shot deviation to $b'' < b_{ss}$ profitable. This bank's problem is given by:

$$\max_{b',b''} \; R - \lambda b + \tilde{q}(b',b'')[b' - (1-\lambda)b] + \frac{1}{r}\left\{\int_{-\tilde{v}^e(b',b'')}^{\bar{z}}[z' + \tilde{v}^e(b',b'')]d\Phi(z')\right\} \tag{36}$$

where

$$\tilde{q}(b',b'')b' = \frac{1}{r}\left\{[\mu(B) + \lambda + (1-\lambda)q(b'')]b' + \int_{-\bar{z}}^{-\tilde{v}^e(b',b'')}[z' + \tilde{v}^e(b',b'') - \xi b']d\Phi(z')\right\}. \tag{37}$$

Differentiate the objective in (36) with respect to b''. Since $\frac{\partial \tilde{v}^e(b',b'')}{\partial b''}|_{b'=b''=b_{ss}} = 0$, the derivative at $b = b' = b'' = b_{ss}$ is given by:

$$\lambda b_{ss} \frac{\partial \tilde{q}(b',b'')}{\partial b''}|_{b'=b''=b_{ss}}. \tag{38}$$

To show that (38) is strictly negative, it is sufficient to show that $\frac{\partial \tilde{q}(b',b'')}{\partial b''}|_{b'=b''=b_{ss}} < 0$.

Differentiate (37) with respect to b'' and then evaluate at steady state:

$$\frac{\partial \tilde{q}(b',b'')}{\partial b''}|_{b'=b''=b_{ss}} = \frac{1}{r}(1-\lambda)\frac{\partial q(b'')}{\partial b''}|_{b''=b_{ss}}.$$

Here we again utilize that $\frac{\partial \tilde{v}^e(b',b'')}{\partial b''}|_{b'=b''=b_{ss}} = 0$. Condition (i), i.e. $\frac{\partial q(b')}{\partial b'}|_{b'=b_{ss}} < 0$, and (ii), i.e. $\lambda < 1$, together imply that $\frac{\partial \tilde{q}(b',b'')}{\partial b''}|_{b'=b''=b_{ss}} < 0$.

A.4 Proposition 5

Plug (10) into (9) and then use (16). We can rewrite the objective of the regulator with partial commitment to equity values into:

$$R + \mu(B)B - \xi B\Phi(-V^e) + \frac{1}{r}H(B', V^{e\prime}) = V^e - \xi B\Phi(-V^e) + V^b(B, Q(B', V^{e\prime}))B.$$

Rewrite the problem of a regulator with partial commitment to equity values into

$$H(B, V^e) = \max_{B'} V^e - \xi B\Phi(-V^e) + V^b(B, Q(B', U(B', B, V^e)))B \tag{39}$$

where $U(B', B, V^e)$ is given implicitly by:

$$\begin{aligned} V^e = R - \lambda B + Q(B', U(B', B, V^e))[B' - (1-\lambda)B] \\ + \frac{1}{r}\Big\{ \int_{-U(B',B,V^e)}^{\bar{z}} [U(B', B, V^e) + z'] d\Phi(z') \Big\}, \end{aligned} \tag{40}$$

given pricing schedule

$$Q(B', V^{e\prime})B' = \frac{1}{r}\Big\{ V^b(B', Q\,(')) + \int_{-\bar{z}}^{-V^{e\prime}} [z' + V^{e\prime} - \xi B'] d\Phi(z') \Big\}. \tag{41}$$

with $Q\left('\right) \equiv Q\left(h_B\left(B', V^{e\prime}\right), U\left(h_B\left(B', V^{e\prime}\right), B', V^{e\prime}\right)\right)$ and $h_B(.)$ solving (39). In other words, given the pricing schedule, $U(B', B, V^e)$ denotes the choice for $V^{e\prime}$ that can satisfy prior promise V^e given the choice for B' and policy of the future regulator.

Denote steady state values under the partial commitment regulator with subscript ss. We know from first-order condition that

$$\partial Q^B_{ss} + \partial Q^V_{ss} \partial U_{ss} = 0.$$

where we define $\partial Q^B \equiv \frac{\partial Q(B', V^{e\prime})}{\partial B'}$, $\partial Q^V \equiv \frac{\partial Q(B', V^{e\prime})}{\partial V^{e\prime}}$, and $\partial U \equiv \frac{\partial U(B', B, V^e)}{\partial B'}$. By differentiating (40), we have

$$\lambda B_{ss} \partial Q^B_{ss} + Q_{ss} + \left[\lambda B_{ss} \partial Q^V_{ss} + \frac{1}{r}\left(1 - \Phi_{ss}\right)\right] \partial U_{ss} = 0.$$

Substitute out ∂U_{ss} and we have in steady state:

$$\partial Q^B_{ss} - \partial Q^V_{ss} \frac{\lambda B_{ss} \partial Q^B_{ss} + Q_{ss}}{\lambda B_{ss} \partial Q^V_{ss} + \frac{1}{r}\left(1 - \Phi_{ss}\right)} = 0. \tag{42}$$

We consider a regulator who chooses B' and B'' today at time t and follows the optimal policy of a partial commitment regulator beyond $t+2$. Our goal is to show the condition under which the derivative of its objective with respect to B'' is 0 when evaluated at the point implied by (42).

This regulator's problem is given by:

$$\begin{aligned} \max_{B', B''} \; & R + \mu(B)B - \xi B \Phi\left(-V^e\right) \\ & + \frac{1}{r}\left\{R + \mu(B')B' - \xi B' \Phi(-\tilde{U}\left(B', B'', B, V^e\right))\right\} + \frac{1}{r^2} H(B'', \hat{U}(B', B'', B, V^e)), \end{aligned} \tag{43}$$

where today's promise $\tilde{U}(B', B'', B, V^e)$ is given by

$$\begin{aligned} V^e = R - \lambda B + & \tilde{Q}(B', B'', B, V^e)[B' - (1-\lambda)B] \\ & + \frac{1}{r}\left\{\int_{-\tilde{U}(B', B'', B, V^e)}^{\bar{z}} [\tilde{U}(B', B'', B, V^e) + z'] d\Phi(z')\right\} \end{aligned} \tag{44}$$

and tomorrow's promise $\hat{U}(B', B'', B, V^e) \equiv U(B'', B', \tilde{U}(B', B'', B, V^e))$ is given by

$$\tilde{U}(B', B'', B, V^e) = R - \lambda B' + Q(B'', \hat{U}(B', B'', B, V^e))[B'' - (1-\lambda)B'] + \frac{1}{r}\left\{\int_{-\hat{U}(B',B'',B,V^e)}^{\bar{z}} [\hat{U}(B', B'', B, V^e) + z']d\Phi(z')\right\}, \quad (45)$$

given

$$\tilde{Q}(B', B'', B, V^e)B' = \frac{1}{r}\Bigg\{V^b(B', Q(B'', \hat{U}(B', B'', B, V^e))) + \int_{-\bar{z}}^{-\tilde{U}(B',B'',B,V^e)} [z' + \tilde{U}\left(B', B'', B, V^e\right) - \xi B']d\Phi(z')\Bigg\}. \quad (46)$$

Plug (46) into (44):

$$\begin{aligned}
&V^e - \xi B\Phi\left(-V^e\right) + V^b(B, \tilde{Q}(B', B'', B, V^e)) \\
&= R - \xi B\Phi\left(-V^e\right) + \mu(B)B \\
&+ \frac{1}{r}\left[V^b(B', Q(B'', \hat{U}(B', B'', B, V^e))) + \tilde{U}\left(B', B'', B, V^e\right) - \xi B'\Phi(-\tilde{U}\left(B', B'', B, V^e\right))\right].
\end{aligned}$$

Manipulate (45) using (41) and (16):

$$\begin{aligned}
&\tilde{U}(B', B'', B, V^e) + V^b(B', Q(B'', \hat{U}(B', B'', B, V^e))) - \xi B'\Phi(-\tilde{U}\left(B', B'', B, V^e\right)) \\
&= R + L(B')B' - \xi B'\Phi(-\tilde{U}\left(B', B'', B, V^e\right)) + \frac{1}{r}H(B'', \hat{U}(B', B'', B, V^e)).
\end{aligned}$$

Based on the above two equations, we can rewrite the objective of this regulator with a one-shot deviation opportunity as:

$$\max_{B',B''} V^e - \xi B\Phi(-V^e) + V^b(B, \tilde{Q}(B', B'', B, V^e)). \quad (47)$$

Now we are ready to show the condition under which the derivative of (47) with respect to B'' is 0 when evaluated at the point implied by (42), that is,

$$(1-\lambda)B_{ss}\frac{\partial\tilde{Q}(B', B'', B, V^e)}{\partial B''}_{ss} = 0. \quad (48)$$

Differentiate (44), (45), and (46) with respect to B''. We end up with three equations that allow us to solve for $\frac{\partial \tilde{Q}(B',B'',B,V^e)}{\partial B''}_{ss}$, $\frac{\partial \tilde{U}(B',B'',B,V^e)}{\partial B''}_{ss}$, and $\frac{\partial \hat{U}(B',B'',B,V^e)}{\partial B''}_{ss}$. Tedious algebra yield:

$$\frac{\partial \tilde{Q}(B',B'',B,V^e)}{\partial B''}_{ss}\left[1+\frac{1-\lambda}{1-\Phi_{ss}}\frac{\frac{\lambda}{1-\Phi_{ss}}B_{ss}\partial Q^V_{ss}}{\frac{\lambda}{1-\Phi_{ss}}B_{ss}\partial Q^V_{ss}+\frac{1}{r}}+(\xi B_{ss}\phi_{ss}+\Phi_{ss})\frac{\lambda}{1-\Phi_{ss}}\right]$$
$$=\frac{1}{r}(1-\lambda)\left[\partial Q^B_{ss}-\partial Q^V_{ss}\frac{\lambda B_{ss}\partial Q^B_{ss}+Q_{ss}}{\lambda B_{ss}\partial Q^V_{ss}+\frac{1}{r}(1-\Phi_{ss})}\right], \tag{49}$$

of which the right-hand side is 0 by (42). It is easy to verify using (42) that if

$$\partial Q^B_{ss}\neq-\frac{Q_{ss}[1-\Phi_{ss}+(\xi B_{ss}\phi_{ss}+\Phi_{ss})\lambda]}{B_{ss}\left[1-\Phi_{ss}+1-\lambda+(\xi B_{ss}\phi_{ss}+\Phi_{ss})\lambda\right]\lambda},$$

the second term on the left-hand side of (49) is not 0. This implies that $\frac{\partial \tilde{Q}(B',B'',B,V^e)}{\partial B''}_{ss}=0$.

A.5 Proposition 6

The Lagrangian for our sequential Ramsey regulator with non-maturing deposits is

$$\max_{\left\{\substack{V^e_t(R^t),Q_t(R^t)\\ B_{t+1}(R^t),\gamma_t(R^t),\zeta_t(R^t)}\right\}_{t=0}^{\infty}} \mathbf{E}_0\sum_{t=0}^{\infty}\frac{1}{r^t}\Bigg\{R_t+L(B_t,Q_t)B_t-\xi B_t\Phi(-V^e_t)$$
$$+\gamma_t\Bigg\{R_t-\lambda(Q_t)B_t+Q_t[B_{t+1}-(1-\lambda(Q_t))B_t]$$
$$+\frac{1}{r}\mathbf{E}_t\left[\int_{-V^e_{t+1}}^{\bar{z}}(z+V^e_{t+1})d\Phi(z)\right]-V^e_t\Bigg\}$$
$$+\zeta_t\Bigg\{\frac{1}{r}\mathbf{E}_t\Bigg[\left[L(B_{t+1},Q_{t+1})+\lambda(Q_{t+1})+(1-\lambda(Q_{t+1}))Q_{t+1}\right]B_{t+1}$$
$$+\int_{-\bar{z}}^{-V^e_{t+1}}(z+V^e_{t+1}-\xi B_{t+1})d\Phi(z)\Bigg]-Q_tB_{t+1}\Bigg\}\Bigg\},$$

where $L(B_t,Q_t)=\mu(B_t)+\int_{Q_t+\kappa-1}^{\bar{\nu}}(\nu-\kappa)dF(\nu)$ and $\lambda(Q_t)=1-F(Q_t+\kappa-1)$; γ_t and ζ_t are two Lagrange multipliers; R^t is the history of shocks up till time t; B_0 is predetermined.

First-order conditions in state R^t at time t are given by:

$$
\begin{aligned}
&\frac{1}{r}\mathbf{E}_t\{L_{t+1} + B_{t+1}L^B_{t+1} - \xi\Phi(-V^e_{t+1}) - \gamma_{t+1}[\lambda_{t+1} + Q_{t+1}(1-\lambda_{t+1})]\} + \gamma_t Q_t \\
&+ \zeta_t\left\{\frac{1}{r}\mathbf{E}_t[\lambda_{t+1} + L_{t+1} + B_{t+1}L^B_{t+1} + (1-\lambda_{t+1})Q_{t+1} - \xi\Phi(-V^e_t)] - Q_t\right\} = 0, && (50)\\
&L^Q_t B_t + \gamma_t[-\lambda^Q_t B_t + B_{t+1} - (1-\lambda_t)B_t + \lambda^Q_t Q_t B_t] \\
&\qquad - \zeta_t B_{t+1} + \zeta_{t-1}(\lambda^Q_t + L^Q_t + 1 - \lambda_t - \lambda^Q_t Q_t)B_t = 0, && (51)\\
&\xi\phi(-V^e_t)B_t - \gamma_t + \gamma_{t-1}[1-\Phi(-V^e_t)] + \zeta_{t-1}[\Phi(-V^e_t) + \xi\phi(-V^e_t)B_t] = 0, && (52)
\end{aligned}
$$

where L^B and L^Q represent derivatives of $L(B_t, Q_t)$ with respect to B_t and Q_t respectively; λ^Q represents the derivative of $\lambda(Q_t)$ with respect to Q_t.

Define $\gamma^*_t = \gamma_t + 1$ and $\zeta^*_t = \zeta_t + 1$. Set deposits, equity value and deposit price to their steady-state levels, i.e. B_{ss}, V^e_{ss} and Q_{ss}. Equations (50), (52) and (51) evolve into:

$$
\begin{aligned}
&\gamma^*_{t+1} = A^0\gamma^*_t + A^1\zeta^*_t, && (53)\\
&\gamma^*_t = B^0\gamma^*_{t-1} + B^1\zeta^*_{t-1}, && (54)\\
&\zeta^*_t = \Omega_{ss}B^0\gamma^*_{t-1} + [\Omega_{ss}B^1 + (1 + L^Q_{ss} - \Omega_{ss})]\zeta^*_{t-1}, && (55)
\end{aligned}
$$

where $\Omega_{ss} = \lambda_{ss} + (Q_{ss} - 1)\lambda^Q_{ss}$ and

$$
\begin{aligned}
A^0 &= \frac{rQ_{ss}}{\lambda_{ss} + (1-\lambda_{ss})Q_{ss}},\\
A^1 &= \frac{\lambda_{ss} + L_{ss} + B_{ss}L^B_{ss} + (1-\lambda_{ss})Q_{ss} - \xi\Phi(-V^e_{ss}) - rQ_{ss}}{\lambda_{ss} + (1-\lambda_{ss})Q_{ss}},\\
B^0 &= 1 - \Phi(-V^e_{ss}),\\
B^1 &= \Phi(-V^e_{ss}) + \xi\phi(-V^e_{ss})B_{ss}.
\end{aligned}
$$

Some manipulations yield:

$$
\zeta^*_t = \left\{[\Omega_{ss}B^1 + (1 + L^Q_{ss} - \Omega_{ss})] - \Omega_{ss}B^0\frac{A^1 - B^1}{A^0 - B^0}\right\}\zeta^*_{t-1}.
$$

We know that $(A^0 - B^0)\gamma_t^* + (A^1 - B^1)\zeta_t^* = 0$, which means that

$$\left\{[\Omega_{ss}B^1 + (1 + L_{ss}^Q - \Omega_{ss})] - \Omega_{ss}B^0\frac{A^1 - B^1}{A^0 - B^0} + A^1\frac{A^0 - B^0}{A^1 - B^1} - A^0\right\}\zeta_{t-1}^* = 0.$$

Setting the term in the bracket to zero gives us the condition we need in addition to two constraints to solve for B_{ss}, Q_{ss} and V_{ss}^e. We verify numerically that under our calibration there exists a $\{B_{ss}, Q_{ss}, V_{ss}^e\}$ that solves these three equations. However, $1 < [\Omega_{ss}B^1 + (1 + L_{ss}^Q - \Omega_{ss})] - \Omega_{ss}B^0\frac{A^1-B^1}{A^0-B^0} < r$. This serves a counter-example against constant Lagrange multipliers.

B Partial commitment to deposit prices

The problem of the regulator with partial commitment to deposit prices can be split into a continuation problem and an initial problem. The continuation problem is given by:

$$H(B, Q) = \max_{B',Q'} R + \mu(B)B - \xi B\Phi(-V^e(B', Q'; B, Q)) + \frac{1}{r}H(B', Q'), \tag{56}$$

subject to a promise keeping constraint on deposit price:

$$QB' = \frac{1}{r}\left\{\int_{-V^e(')}^{\bar{z}} V^b(B', Q')d\Phi(z') + \int_{-\bar{z}}^{-V^e(')} [z' + V^e(') + V^b(B', Q') - \xi B']d\Phi(z')\right\},$$

given an equity value schedule:

$$V^e(B', Q'; B, Q) = R - \lambda B + Q[B' - (1 - \lambda)B] + \frac{1}{r}\left\{\int_{-V^e(')}^{\bar{z}} [V^e(') + z']d\Phi(z')\right\},$$

where $V^e(') \equiv V^e(h_B(B', Q'), h_Q(B', Q'); B', Q')$ with $h_B(B, Q)$ and $h_Q(B, Q)$ being optimal policies for deposits B' and promised deposit price Q' from (56); depositors' value is $V^b(B, Q) = [\mu(B) + \lambda + (1 - \lambda)Q]B$.

Initially, given B_0, the regulator chooses:

$$\max_{Q_0} H(B_0, Q_0).$$

C One-shot commitments with non-maturing deposits

It is straightforward to show that Propositions 1 and 2 carry through into our extended model with non-maturing deposits. First, the sequential problem of a Ramsey regulator can be reformulated into a continuation problem and an initial problem, with the former being recursive. In the case with shocks, promised equity values and deposit prices in the continuation problem are contingent on states next period R', that is, given current state $\{R, B, V^e, Q\}$, a Ramsey regulator chooses $\{B', V^{e\prime}(R'), Q'(R')\}$; in the initial problem the regulator picks a pair of $\{V_0^e, Q_0\}$ for each R_0. Second, the regulators' objective $H = V^e + V^b(B,Q) - \xi B \Phi(-V^e)$ where $V^b(B,Q) = \{L(B,Q) + \lambda(Q) + [1-\lambda(Q)]Q\}B$ with $\lambda(.)$ and $L(.)$ given by (21) and (22). While we do not provide a detailed proof here to save space, they are available upon request.

C.1 Regulator's time inconsistency problem

We now show the value of commitment via a one-shot deviation exercise similar to Section 3. Proposition 7 generalizes Proposition 3 into this extended setup. In particular, a Markov-perfect regulator can improve total value today by deviating in one shot to a higher deposit issuance tomorrow when deposit maturity is long enough, if granted with such an ability to commit. In the fixed-maturity case, by committing to a higher deposit issuance tomorrow, risk-adjusted payments to legacy deposits decline and equity value today increases. With endogenous maturity, as expected payments to unwithdrawn deposits decline, more depositors will end up withdrawing today. This additional channel of withdrawals can either amplify or dampen the increase in equity value depending on whether deposits are valued above or below par—the former case implies a rollover gain and the latter a rollover loss. Overall, equity value today improves as long as the former channel is dominant—that is, when the equilibrium mass of non-withdrawing depositors $1 - \lambda_{ss}$ is large.

Proposition 7 *In an interior steady state, a Markov-perfect regulator improves total value today by committing to a small one-shot deviation to a larger issuance tomorrow if (i) deposit pricing function $Q(.)$ decreases in B' at $B' = B_{ss}$ and (ii) deposit maturity $\lambda_{ss} < \min\{1 + \frac{1+\xi B_{ss}\phi_{ss}}{\xi B_{ss}\phi_{ss}} (Q_{ss} - 1) f_{ss}, 1\}$ where subscript ss denotes steady state values.*

Proof. The proof follows the same structure as Appendix A.2, and to save space, we here highlight only the differences. Fix productivity R to be constant so that it is no longer an argument of any functions. We consider a regulator who chooses B' and B'' today at time t and follows the optimal policy of a Markov-perfect regulator beyond $t+2$. The first-order condition with respect to B'' (generalizing (34)) is:

$$\{\xi B_{ss}\phi_{ss}\left[f_{ss}(1-Q_{ss})-(1-\lambda_{ss})\right]+f_{ss}(1-Q_{ss})\}\, B_{ss}\frac{\partial\tilde{Q}(B',B'')}{\partial B''}|_{B'=B''=B_{ss}}, \tag{57}$$

where subscript ss denotes steady state values; $\tilde{Q}(B',B'')$ is the deposit price at time t given the choice $\{B',B''\}$.

Condition (ii), i.e. $\lambda_{ss} < 1+\frac{1+\xi B_{ss}\phi_{ss}}{\xi B_{ss}\phi_{ss}}\left(Q_{ss}-1\right)f_{ss}$, guarantees that the first term of (57) is negative. Conditions (i) and (ii), i.e. $\lambda_{ss} < 1$, together imply that $\frac{\partial\tilde{Q}(B',B'')}{\partial B''}|_{B'=B''=B_{ss}} < 0$. ■

Proposition 8 generalizes Proposition 4 into this extended setup. In particular, a bank in laissez-faire has an incentive to deviate to a low deposit issuance tomorrow when deposit maturity is long, if granted with such an ability to commit. This commitment increases the price at which new deposits can be issued today and in turn benefits equity value. With endogenous maturity, fewer depositors will end up withdrawing expecting a smaller default risk tomorrow. Overall, equity value improves as long as new issuance λ_{ss} every period is nontrivial.

Proposition 8 *In an interior steady state, a laissez-faire bank improves equity value today by committing to a small one-shot deviation to a lower issuance tomorrow if (i) deposit pricing function $q(.)$ decreases in b' at $b'=b_{ss}$ and (ii) deposit maturity $\lambda_{ss} < 1$ and $\lambda_{ss} > (q_{ss}-1)f_{ss}$ where subscript ss denotes steady state values.*

Proof. The proof follows the same structure as Appendix A.3, and to save space, we here highlight only the differences. Fix productivity R to be constant so that it is no longer an argument of any functions. We consider a bank who chooses b' and b'' today at time t and follows the optimal policy of a laissez-faire bank without commitment beyond $t+2$. The first-order condition with respect to B'' (generalizing (38)) is:

$$\left[\lambda_{ss}-(q_{ss}-1)f_{ss}\right] b_{ss}\frac{\partial\tilde{q}(b',b'')}{\partial b''}|_{b'=b''=b_{ss}}, \tag{58}$$

where subscript ss denotes steady state values; $\tilde{q}(b', b'')$ is the deposit price at time t given the choice $\{b', b''\}$.

Condition (ii), i.e. $\lambda_{ss} > (q_{ss} - 1)f_{ss}$, guarantees that the first term of (58) is positive. Conditions (i) and (ii), i.e. $\lambda_{ss} < 1$, together imply that $\frac{\partial \tilde{q}(b',b'')}{\partial b''}|_{b'=b''=b_{ss}} < 0$.

■

C.2 Partial commitment

Now we present the problem of a regulator with partial commitment to equity values in our extended model with non-maturing deposits. We then show that there is no profitable one-shot deviation in steady state, again echoing our baseline results in Section 3. Numerically we solve the model and confirm that the steady states of two regulators with partial commitment are identical to that of Ramsey. We do not present our numerical solutions for the partial commitment regulators in the main text.

As we mentioned earlier, with shocks, promised values in the continuation problem of a recursively-formulated Ramsey regulator are state-contingent. The problem of a regulator committing to equity values can also be split into a continuation problem and an initial problem. The continuation problem is given recursively:

$$H(R, B, V^e) = \max_{B', V^{e\prime}(R')} R + L(B, Q(B', V^{e\prime}(R'); R))B - \xi B \Phi(-V^e) + \frac{1}{r}\mathbf{E} H(R', B', V^{e\prime}(R')), \tag{59}$$

subject to promise keeping to equity value V^e:

$$\begin{aligned} V^e = {} & R - \lambda(Q(B', V^{e\prime}(R'); R))B \\ & + Q(B', V^{e\prime}(R'); R)\{B' - [1 - \lambda(Q(B', V^{e\prime}(R'); R))]B\} + \frac{1}{r}\mathbf{E}\left\{\int_{-V^{e\prime}(R')}^{\bar{z}} [V^{e\prime}(R') + z'] d\Phi(z')\right\}, \end{aligned}$$

given a deposit pricing schedule:

$$\begin{aligned} Q(B', V^{e\prime}(R'); R)B' = \frac{1}{r}\mathbf{E}\Big\{ & V^b(B', Q(h_B(R', B', V^{e\prime}(R')), h_{V^e}(R''; R', B', V^{e\prime}(R')); R')) \\ & + \int_{-\bar{z}}^{-V^{e\prime}(R')} [z' + V^{e\prime}(R') - \xi B'] d\Phi(z')\Big\}, \end{aligned}$$

where $V^b(B,Q) = \{\lambda(Q) + L(B,Q) + [1-\lambda(Q)]Q\}B$; $\lambda(.)$ and $L(.)$ are given by (21) and (22); $h_B(R,B,V^e)$ and $h_{V^e}(R';R,B,V^e)$ together solve (59).

Initially, given B_0 and R_0, the regulator chooses:

$$\max_{V_0^e} H(R_0, B_0, V_0^e).$$

Proposition 9 generalizes Proposition 5 into this extended setup. In particular, the partial-commitment regulator in steady state, if granted with the ability to commit in one shot to deposit issuance tomorrow, has no incentive to deviate. The intuition is similar to that for Proposition 5. In short, one type of commitment is sufficient to align regulator's incentives across time in the continuation problem.

Proposition 9 *In an interior steady state with $\lambda_{ss} < 1$, a regulator with partial commitment to equity values cannot improve total value today by committing to a small one-shot deviation in issuance tomorrow if the derivative of deposit pricing function $Q(.)$ with respect to B' at $\{B' = B_{ss}, V^{e\prime} = V^e_{ss}\}$ does not equal $-\frac{Q_{ss}\{1-\Phi_{ss}+(\xi B_{ss}\phi_{ss}+\Phi_{ss})[f_{ss}(1-Q_{ss})+\lambda_{ss}]\}}{B_{ss}\{1-\Phi_{ss}+1-\lambda_{ss}+(\xi B_{ss}\phi_{ss}+\Phi_{ss})[f_{ss}(1-Q_{ss})+\lambda_{ss}]\}[f_{ss}(1-Q_{ss})+\lambda_{ss}]}$ where subscript ss denotes steady state values.*

Proof. The proof follows the same structure as Appendix A.4, and to save space, we here highlight only the differences. Fix productivity R to be constant so that it is no longer an argument of any functions.

The first-order condition for the partial-commitment regulator (generalizing (42)) implies:

$$\partial Q^B_{ss} - \partial Q^V_{ss} \frac{[f_{ss}(1-Q_{ss}) + \lambda_{ss}]\, B_{ss} \partial Q^B_{ss} + Q_{ss}}{[f_{ss}(1-Q_{ss}) + \lambda_{ss}]\, B_{ss} \partial Q^V_{ss} + \frac{1}{r}(1-\Phi_{ss})} = 0. \tag{60}$$

where subscript ss denotes steady state values; $\partial Q^B \equiv \frac{\partial Q(B', V^{e\prime})}{\partial B'}$ and $\partial Q^V \equiv \frac{\partial Q(B', V^{e\prime})}{\partial V^{e\prime}}$.

We consider a regulator who chooses B' and B'' today at time t and follows the optimal policy of a partial commitment regulator beyond $t+2$. We would like to show the condition under which the first-order derivative of its objective with respect to B'' is 0 when evaluated at the point implied by (60), that is (generalizing (48)),

$$(1-\lambda_{ss}) B_{ss} \left.\frac{\partial \tilde{Q}(B', B'', B, V^e)}{\partial B''}\right|_{ss} = 0,$$

where $\tilde{Q}(B', B'', B, V^e)$ is the deposit price at time t given the choice $\{B', B''\}$ and state variables B and V^e. Differentiating two promise keeping constraints and deposit pricing function, we get (generalizing (49)):

$$\left.\frac{\partial \tilde{Q}(B', B'', B, V^e)}{\partial B''}\right|_{ss}$$
$$\times \left[1 + \frac{1-\lambda_{ss}}{1-\Phi_{ss}} \frac{\frac{f_{ss}(1-Q_{ss})+\lambda_{ss}}{1-\Phi_{ss}} B_{ss} \partial Q^V_{ss}}{\frac{f_{ss}(1-Q_{ss})+\lambda_{ss}}{1-\Phi_{ss}} B_{ss} \partial Q^V_{ss} + \frac{1}{r}} + (\xi B_{ss}\phi_{ss} + \Phi_{ss}) \frac{f_{ss}(1-Q_{ss}) + \lambda_{ss}}{1-\Phi_{ss}}\right]$$
$$= \frac{1}{r}(1-\lambda_{ss}) \left\{\partial Q^B_{ss} - \partial Q^V_{ss} \frac{[f_{ss}(1-Q_{ss}) + \lambda_{ss}] B_{ss} \partial Q^B_{ss} + Q_{ss}}{[f_{ss}(1-Q_{ss}) + \lambda_{ss}] B_{ss} \partial Q^V_{ss} + \frac{1}{r}(1-\Phi_{ss})}\right\}. \tag{61}$$

The right-hand side of (61) is 0 by (60). It is easy to verify using (60) that if

$$\partial Q^B_{ss} \neq -\frac{Q_{ss}\{1-\Phi_{ss} + (\xi B_{ss}\phi_{ss} + \Phi_{ss})[f_{ss}(1-Q_{ss}) + \lambda_{ss}]\}}{B_{ss}\{1-\Phi_{ss} + 1 - \lambda_{ss} + (\xi B_{ss}\phi_{ss} + \Phi_{ss})[f_{ss}(1-Q_{ss}) + \lambda_{ss}]\}[f_{ss}(1-Q_{ss}) + \lambda_{ss}]},$$

the second term on the left-hand side of (61) is not 0. This implies that $\left.\frac{\partial \tilde{Q}(B', B'', B, V^e)}{\partial B''}\right|_{ss} = 0$.

■

D Empirical analyses: robustness

D.1 Alternative proxies for regulatory commitment

While our preferred proxy for government commitment is the Factor 1.5 *WJP Rule of Law Index*, we experiment with alternative rule of law measures here. Table 4 replicates columns (1) and (2) of Table 3 in the main text with these measures. In columns (1) and (2), we use Factor 1 WJP Rule of Law Index. In columns (3) and (4), we use the overall WJP Rule of Law Index. In columns (5) and (6), we use the rule of law measure from the WGI dataset, and in this case we can directly use the index values 2011 without having to backward fill them. Our main results in Table 3 hold under these measures. For some specifications, the estimated β_4 falls slightly below the 10% significance level with a correct negative sign. Nonetheless, readers shall be cautious in interpreting these results since these rule of law measures are based on questions that are less closely related to our concept of regulatory commitment—e.g., the Factor 1 WJP Rule of Law Index contains responses to questions about whether government officials are sanctioned for misconduct; the WGI Rule of Law Index contains responses to questions about whether respondents have experienced business crimes or violence.

D.2 Alternative measure of crisis severity

We now transform our measure of crisis severity in the main text $GDPdrop$ into a dummy variable $d\_GDPdrop$ to alleviate concerns about outliers. In particular, the dummy variable is equal to 1 for country i if its GDP between 2008, 2009 and 2010 had ever dropped below the 2007 level and to 0 otherwise, i.e. $d\_GDPdrop_i = \mathbf{1}_{\min_{t\in[2008,2010]} GDP_{i,t} < GDP_{i,2007}}$. Panel A of Table 5 repeats our regressions in the main text by replacing $GDPdrop$ with the dummy variable $d\_GDPdrop$. Columns (1) and (2) replicate (1) and (2) of Table 2, and columns (3) and (4) replicate columns (1) and (2) in Panel A of Table 3. Columns (5) and (6) replicate (3) and (4) of Table 2, and columns (7) and (8) replicate columns (1) and (2) in Panel B of Table 3. Overall, our two key results reported in the main text are robust.

Panel B of Table 5 conducts a placebo test. In particular, we replace $GDPdrop$ in the main text with $GDPdrop_i^{05-07} = 100 \times \left(1 - \frac{\min_{t\in[2005,2007]} GDP_{i,t}}{GDP_{i,2004}}\right)$, which describes how GDP of a country behaves prior to the 2008 crisis. We expect post-crisis capital regulation stringency to not depend on this measure. Indeed, we find that none of our estimated coefficients for the interaction term remains statistically significant. Without tabulating an additional panel here to save space, we have also experimented with $GDPdrop_i^{02-04} = 100 \times \left(1 - \frac{\min_{t\in[2002,2004]} GDP_{i,t}}{GDP_{i,2001}}\right)$ and ended up getting similar results.

Table 4: **Regulatory commitment: alternative measures**

Panels A and B first sort countries into three portfolios (*High, Medium, Low*) based on $Quality_{i,2011}$ and $Effectvns_{i,2011}$ respectively, and then estimate (27) for the *High* portfolio. Dependent variable is Cap_{2011}. Independent variable *Comm* is Factor 1 WJP Rule of Law Index in (1) and (2); overall WJP Rule of Law Index in (3) and (4); WGI Rule of Law Index in (5) and (6). Control variables include log real GDP in 2011 and the regulation objective measure in 2011, i.e. $Quality_{i,2011}$ in panel A and $Effectvns_{i,2011}$ in panel B. Standard errors are in parentheses. ***/**/* denotes 99%/95%/90% significance.

	Factor 1 (*WJP*)		*Rule of Law* (*WJP*)		*Rule of Law* (*WGI*)	
	(1)	(2)	(3)	(4)	(5)	(6)
			Panel A. *High Quality*			
Comm × *GDPdrop*	-1.117	-1.019	-1.645*	-1.527*	-0.206	-0.219
	(0.661)	(0.700)	(0.831)	(0.868)	(0.130)	(0.130)
GDPdrop	0.785	0.725	1.142*	1.062*	0.126	0.138
	(0.473)	(0.493)	(0.575)	(0.598)	(0.126)	(0.130)
Comm	-3.957	-2.462	-4.346	-1.556	-0.585	-0.436
	(3.531)	(4.746)	(3.820)	(6.905)	(0.465)	(1.001)
Cap_{2006}	0.493***	0.498**	0.477***	0.498***	0.483***	0.486***
	(0.175)	(0.179)	(0.170)	(0.176)	(0.154)	(0.158)
Controls	No	Yes	No	Yes	No	Yes
R^2	0.333	0.369	0.369	0.395	0.336	0.384
Obs	28	28	28	28	34	34
			Panel B. *High Effectvns*			
Comm × *GDPdrop*	-2.636**	-2.205*	-3.376**	-3.251**	-0.292*	-0.314**
	(1.018)	(1.101)	(1.218)	(1.263)	(0.155)	(0.153)
GDPdrop	1.858**	1.568*	2.375**	2.300**	0.215	0.242*
	(0.721)	(0.783)	(0.855)	(0.894)	(0.139)	(0.140)
Comm	-0.371	1.962	-0.880	6.023	-0.569	0.253
	(3.168)	(3.859)	(3.722)	(5.885)	(0.476)	(1.043)
Cap_{2006}	0.528***	0.536***	0.522***	0.537***	0.454***	0.445***
	(0.178)	(0.180)	(0.171)	(0.170)	(0.157)	(0.153)
Controls	No	Yes	No	Yes	No	Yes
R^2	0.432	0.477	0.470	0.532	0.344	0.425
Obs	26	26	26	26	34	34

Table 5: **Crisis severity: alternative measures**

Panels A and B replace *GDPdrop* in our main analyses with *d_GDPdrop* and $GDPdrop^{05-07}$, respectively. Columns (1) and (2) replicate (1) and (2) of Table 2, and columns (3) and (4) replicate columns (1) and (2) in Panel A of Table 3. Columns (5) and (6) replicate (3) and (4) of Table 2, and columns (7) and (8) replicate columns (1) and (2) in Panel B of Table 3. Standard errors are in parentheses. ***/**/* denotes 99%/95%/90% significance.

	x=Quality		*x=WJP (High-Quality)*		*x=Effectvns*		*x=WJP (High-Effectvns)*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A. Dummy variable *d_GDPdrop*								
$x \times$ *d_GDPdrop*	-0.703*	-0.745	-14.020***	-13.705**	-0.764*	-0.778*	-12.348***	-9.860**
	(0.420)	(0.458)	(4.904)	(4.909)	(0.408)	(0.446)	(4.217)	(4.615)
d_GDPdrop	0.368	0.170	10.037**	9.888**	0.402	0.191	8.366**	6.609*
	(0.443)	(0.498)	(3.679)	(3.669)	(0.446)	(0.491)	(2.985)	(3.266)
x	0.058	-0.128	6.485**	6.752**	0.091	-0.168	8.019**	6.974*
	(0.246)	(0.382)	(3.086)	(3.104)	(0.232)	(0.390)	(3.556)	(3.659)
Cap_{2006}	0.184**	0.192*	0.604***	0.610***	0.186**	0.192*	0.539***	0.544***
	(0.092)	(0.102)	(0.164)	(0.164)	(0.092)	(0.101)	(0.175)	(0.176)
Controls	No	Yes	No	Yes	No	Yes	No	Yes
R^2	0.079	0.112	0.444	0.497	0.084	0.120	0.443	0.492
Obs	103	92	28	28	103	92	26	26
Panel B. Placebo test								
$x \times GDPdrop^{05-07}$	-0.047	-0.078	-1.547	-1.402	-0.045	-0.069	0.079	0.260
	(0.051)	(0.058)	(1.505)	(1.897)	(0.056)	(0.064)	(1.248)	(1.435)
$GDPdrop^{05-07}$	-0.078	-0.104*	1.000	0.883	-0.075	-0.101*	-0.217	-0.235
	(0.051)	(0.061)	(1.099)	(1.336)	(0.051)	(0.060)	(0.872)	(0.957)
x	-0.351	-0.812**	-5.856	-4.877	-0.322	-0.886**	0.854	2.010
	(0.265)	(0.384)	(7.622)	(9.687)	(0.276)	(0.417)	(6.447)	(7.194)
Cap_{2006}	0.201**	0.196*	0.496**	0.509**	0.208**	0.204**	0.498**	0.509**
	(0.093)	(0.101)	(0.180)	(0.183)	(0.093)	(0.100)	(0.207)	(0.200)
Controls	No	Yes	No	Yes	No	Yes	No	Yes
R^2	0.074	0.115	0.281	0.331	0.071	0.116	0.234	0.371
Obs	103	92	28	28	103	92	26	26