Risk-insensitive Regulation[*]

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Abstract

Banking is risky and prone to failure. Yet banking regulation is surprisingly not all that risk-sensitive in practice. I show that when the bank has an informational advantage over the regulator, designing risk-sensitive banking regulation gives rise to a trade-off: relying on the banking market for information to refine regulation improves bank risk-taking but also aggravates the market's allocative failure and could undermine its informativeness. This tension could explain why Basel capital regulations and deposit insurance are often coarse or risk-insensitive. Paradoxically, as market frictions become more severe, optimal regulation becomes ever more risk-insensitive. Only risk-insensitive regulation necessitates a system-wide approach.

Keywords: Bank capital regulation, risk-taking, systemic risk, mechanism design.

JEL classifications: D61, D62, D82, G21, G28.

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1 Introduction

This paper studies the design of bank regulation, and points out a conceptual shortcoming of setting risk-sensitive regulation. Designing risk-sensitive regulation requires information. When the bank has an informational advantage over the regulator, I show that designing risk-sensitive regulation gives rise to a tradeoff: eliciting information from banks to refine regulation could improve bank risk-taking but also increase systemic risk in the banking market and undermine its informativeness.

Financial stability is a public good. The 2007-8 financial crisis however underscored the instability of the banking sector and reignited a decades-long debate about its regulation. The latest response by regulators gave rise to the 2010 Basel III Accord by the Bank of International Settlements (BIS) that promulgates rules for the centerpiece of bank regulation: the regulation of bank capital. Banks do not internalize all the consequences of their risk-taking resulting in a social cost inflicted on the banking sector as a whole. Such market failure justifies regulation that requires banks to use more of their own equity (skin in the game) when taking risks. Greater risk (taking) then requires stricter regulation: risk-sensitive regulation.

Yet observed capital regulation is not all that risk-sensitive. The first form of risk-based bank capital regulation came into effect in 1989. The standard known as Basel I was based on classifications of bank risk to which the regulation assigned risk weights. The higher the risk weight, the stricter the regulation. Assets received one of four possible risk weights (0, 20%, 50%, 100%), with deemed safest assets (like U.S. treasuries) receiving the lowest weight, and deemed riskiest assets (like ordinary loans) receiving the highest weight. This "flat tax" design treats any two assets in a category the same irrespective of their actual risk. Such crudeness in ignoring more relevant information about risk seems inefficient, if not puzzling. In 2004, Basel II was enacted to overcome this apparent inefficiency by improving "risk-sensitivity" (BIS (2001, p.1)). Since Basel II, the bank has had a choice between

subjecting itself to finer but still coarse classifications or rely on its own information to set risk weights.[1] In response to the apparent ineffectiveness of such regulation in preventing the recent financial crisis, the BIS has been working on amending its standards again toward lower risk-sensitivity.[2] A case in point is the use of the leverage ratio, a measure independent of the riskiness of the bank's assets, to encourage the bank's use of equity and discourage risk-taking.[34]

Similar developments have marked deposit insurance. The central issue of debate on deposit insurance has been its pricing. Deposit insurance in the U.S., as evidenced by the risk-sensitivity of the insurance premium levied by the FDIC, was independent of bank risk until 1991 and has not been all that risk-sensitive since (Pennacchi (2009)). Prior to 1991, these risk assessments were set with the goal of maintaining appropriate reserves in the deposit insurance fund. This design was not based on the riskiness of the individual bank or its consequences for the banking system. It was only following the Federal Deposit Insurance Corporation Improvement Act (FDICIA) of 1991 that these premiums were based on very coarse classifications of bank risk (three levels of bank capitalization and three supervisory rating categories). However, this design led to little risk differentiation between banks (Acharya, Santos, and Yorulmazer (2010)).

The development of such bank regulations poses at least two questions. Should the regulator use all available information to design the regulation? Is perfectly risk-sensitive

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[1] A 2015 survey by the BIS finds that all 27 Basel Committee on Banking Supervision member countries had implemented enhanced risk-based capital regulations by the end of 2013 (www.bis.org/bcbs/publ/d345.htm).

[2] See the BIS releases https://www.bis.org/press/p160324.htm, https://www.bis.org/speeches/sp151010.htm and http://www.bis.org/bcbs/publ/d347.htm.

[3] See the BIS release http://www.bis.org/publ/bcbs270.htm.

[4] A special case of capital regulation is that of so-called (globally) systemically important financial institutions (G-SiFis), introduced in response to the financial crisis in 2011 (see releases by the BIS (http://www.bis.org/publ/bcbs202.pdf) and the Financial Stability Board (http://www.fsb.org/what-we-do/policy-development/systematically-important-financial-institutions-sifis/)). Such G-SiFis are deemed to pose a particular threat to financial stability and as such face additional capital requirements based on their contribution to systemic risk. The design of these additional capital surcharges is based on five buckets of increasing degree of systemic importance.

regulation desirable? This paper shows that these questions are intimately related and that the answers to them reveal a conflict.

Banks engage in risk-taking when making loans. Yet the individual bank does not bear all the consequences of its risk-taking. When bank quality is public information, the regulator can perfectly and costlessly correct the market failure from socially excessive risk-taking. However, when the bank is better informed about its risk than the regulator, this information asymmetry complicates the design of regulation. In designing incentives to elicit the information from banks, the regulator faces a tradeoff: requiring the bank to retain critical exposure to the risk of its loans ("skin in the game") reveals information about its risk but also generates systemic risk.[5] In the attempt to reduce such systemic risk, risk-sensitive regulation counterproductively increases this risk.

Optimal regulation balances the social benefits from risk-taking with its social costs. Just when the benefits of regulation are greatest (when the social cost from risk-taking is high), regulation becomes insensitive to the very risk it seeks to control. The reason is that information about bank risk is not free. If the regulator were privy to bank risk, the social net benefits of the risk allocation would determine the optimal risk-taking by banks. However, the information about bank quality is not freely available, and the regulator needs to rely on bank risk-taking to infer bank risk. Such incentive compatible allocations of risk, which would allow the regulator to learn about bank quality, require that higher-quality banks take more risk (risk-taking must be non-decreasing in bank quality). However, when banks with higher-quality loans (high expected cash flow) are also the ones whose risk-taking causes greater social harm (large externality), the optimal allocation of risk is hump-shaped in bank quality. The pursuit of achieving the socially optimal allocation of risk then forces two bank types to hold the same level of risk, thereby making it impossible for the regulator

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[5] The classic applications of risk retention as a solution to adverse selection and moral hazard problems include among others trading in markets for real goods (Akerlof (1970)), insurance (Rothschild and Stiglitz (1976)), financial securities (Leland and Pyle (1977); Glosten (1989); Biais, Rochet, and Martimort (2000); Chemla and Hennessy (2014)) and labor (Hölmstrom (1979)).

to infer bank quality from that level of risk. The regulation becomes insensitive to the very risk it seeks to control. Put differently, the regulator chooses not to set too fine a test to differentiate banks anticipating that the bank would overinvest in impressing the regulator, with adverse consequences for the system. That is, this socially costly screening is a form of tolerated "regulatory arbitrage". The paradoxical result that risk-reducing regulation could increase risk is reminiscent of the theory of the second best from welfare economics. When there is more than one imperfection in the market (information asymmetry and negative externality), removing one imperfection (information asymmetry) could exacerbate another (negative externality) to the detriment of overall welfare.

This insight could explain why real-world bank capital regulations, like the (early and latest versions of the) Basel Accords, are often coarse or not all that risk-sensitive. The result is also consistent with the "information-light" policies promoted by Tirole (2015). In his 2014 Nobel Prize speech, Tirole urged economists to offer "policies that do not require information that is unlikely to be available to regulators". This paper argues that the reason regulators may choose to implement information-light policies is to avoid the unintended, adverse distortions to the behavior of the regulated firms that information-sensitive policies would cause.

As such, the model could not just shed light on the observed design of capital regulation but also offer three main empirical predictions. First, the model provides an explanation for the puzzling empirical performance of capital regulation, as evidenced by the relationship between measured and actual risk. While risk-sensitive regulation is designed to reflect and control risk, the observed link between measured risk and actual risk is low (Van Hoose (2007); Haldane (2013); Vallascas and Hagendorff (2013); Acharya, Engle, and Pierret (2014)) or even negative (Behn, Haselmann, and Vig (2014); Becker and Opp (2014); Begley, Purnanandam, and Zheng (2016)). That is, at best measures of bank risk appear to be uninformative about actual risk. At worst, there are instances in which capital regulation seems to have increased risk in the banking and insurance sectors, consistent with my

model. My theory shows that risk-sensitive regulation could cause greater risk-taking (skin in the game) in the banking sector in order to become risk-sensitive. While the effect of capital-adequacy requirements is to decrease risk-taking in the theoretical literature, the reverse has also been shown due to distorted portfolio choice (Koehn and Santomero (1980); Lam and Chen (1985); Koehn and Santomero (1988); Flannery (1989); Gennotte and Pyle (1991); Rochet (1992); Acharya (2009)) and lower portfolio quality through reduced monitoring incentives (Besanko and Kanatas (1996); Boot and Greenbaum (1993)). The contribution of my theory is to demonstrate that information asymmetry could cause an optimal regulatory mechanism to tolerate increased risk-taking by design.

The model also offers two novel predictions. Second, it shows that when market frictions (information asymmetry and the cost of systemic risk) become more severe, optimal regulation becomes ever more risk-insensitive. Conventional wisdom holds that the demand for information increases in response to greater information asymmetry. Paradoxically, this paper shows that the demand for information may increasingly fail to exist as the need for information increases. The intuition is simple. When the set of bank types the regulator seeks to distinguish expands, the individual bank would need to hold more skin in the game to overcome the growing information asymmetry. However, when the risk-taking of the additional bank types produces large externalities, such risk-taking becomes ever more socially costly. Likewise, holding the aggregate risk-taking fixed, when the banking sector becomes more sensitive to systemic risk, the bank's skin in the game used to produce the information about bank risk becomes more expensive. In either case, the regulator responds to this increased cost of producing information about bank risk by not eliciting the information, thereby rendering the regulation risk-insensitive.

Third, the model demonstrates that regulation aimed at improving the safety of the system requires a system-wide approach only when the regulation is risk-insensitive. Counterintuitively, regulation that is information-light (risk-insensitive) in fact requires information about the whole set of bank types that are treated identically by the regula-

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tion. As a corollary, when optimal regulation is risk-insensitive, the regulation could be implemented with a Pigouvian (flat) tax whereas a sharper instrument, fine-tuned to the characteristics of the individual bank, is needed when optimal regulation is risk-sensitive. As such, this paper complements the recent literature that proposes the use of Pigouvian taxes to control systemic risk (e.g. Bianchi and Mendoza (2010); Perotti and Suarez (2011); Freixas and Rochet (2013); Coulter, Mayer, and Vickers (2014); Acharya, Pedersen, Philippon, and Richardson (2016)).

Finally, my theory offers a caveat to the coordinated design of bank regulation. Bank capital regulation comes in two forms (see Hansen, Kashyap, and Stein (2011); Fisher (2014)): micro-prudential (aimed at the soundness of the individual institution) and macro-prudential (aimed at the stability of the system as a whole). My theory caveats the familiar truism that any effort to stabilize the individual institution must necessarily stabilize the system (see also Morris and Shin (2008)). I argue that these regulations could be in conflict: attempting to reduce the fragility of the individual bank could exacerbate the instability of the system.

Related literature

The most closely related strand of literature studies the use of information in the design of bank capital regulation. The common theme is that using additional information about the bank should improve the regulation.[6] Marshall and Prescott (2001) and Marshall and Prescott (2006) show that bank regulation based on capital requirements and penalties can reveal information about the bank and improve its risk-taking. McDonald (2010) and Hart and Zingales (2012) argue that using equity and credit default swap prices of the bank improves the efficient intervention by the regulator. In contrast, Faure-Grimaud (2002); Bond, Goldstein, and Prescott (2010) and Lehar, Seppi, and Strobl (2011) caution against

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[6] For surveys on the vast literature on bank regulation see Bhattacharya, Boot, and Thakor (1998); Allen (2004) and Van Hoose (2007).

the use of market-based regulation by arguing that intervening in the market based on the information content of market prices alters their information content and thus undermines their usefulness. In a similar spirit to my paper, Lehar, Seppi, and Strobl (2011) show that not only does the attempt to learn information from the bank affect the information content but it also distorts the risk-taking of the bank. My paper complements both sides of the arguments in the literature by demonstrating that the use of information by the regulator distorts the very activity that produces the information. The resulting tradeoff could then lead the regulator to optimally ignore information. While in the existing theories the source of information is the market price of bank securities, I show that the inefficient distortions to firm behavior caused by the regulation can be part of an optimal contractual arrangement. Since the "skin in the game" mechanism results in the bank retaining more risky assets on its publicly available balance sheet, any outsider to the bank could use this information to refine their interaction with the bank, such as a regulator or market participants. As a consequence, it is possible that this mechanism is the original source of information that is reflected in any transaction outcome, such as market prices, not just the regulatory arrangement between the regulator and the bank.

My paper is also related to the vast theoretical literature on deposit insurance. The main issue in this literature (e.g. Merton (1977, 1978); Ronn and Verma (1986); Pennacchi (1987); Flannery (1991)) is the pricing of deposit insurance. The literature suggests that deposit insurance has not reflected the risk of a bank due to the difficulty (Chan, Greenbaum, and Thakor (1992)) and non-desirability (Freixas and Rochet (1998)) of determining its fair pricing. Acharya, Santos, and Yorulmazer (2010) is the first to argue that optimally designed deposit insurance should be based on the systemic risk contribution by the bank. Charging the bank a fee (corrective tax) that reflects a systemic risk premium should then fully resolve issues with systemic risk (Pennacchi (2006)). While this is true in perfect markets without frictions, I show that the friction of information asymmetry between the bank and outsiders makes fair pricing of deposit insurance more difficult and costly, by

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counterproductively increasing risk, and could explain why deposit insurance is not all that risk-sensitive in practice. Giammarino, Lewis, and Sappington (1993) also studies the design of bank regulation (capital requirements and deposit insurance jointly), and shows that socially optimal regulation is risk-sensitive under asymmetric information. Their focus however is not on systemic risk and controlling the externalities that originate from bank risk-taking.

The rest of the paper is organized as follows. Section 2 describes the model, section 3 presents the equilibria, section 4 states the main results, and section 5 discusses policy implications. Appendix A includes the proofs that are not in the text.

2   Model

The setup is a stylized two-date model of banking with a regulator and a continuum of banks, each of which manages a risky loan. The loan generates a random cash flow $\widetilde{\theta} + \widetilde{x}$ at $t = 1$, where $\widetilde{\theta}$ and $\widetilde{x}$ are two independent random variables.[7] θ, the realization of $\widetilde{\theta}$, is privately observed by the bank at $t = 0$. θ is drawn from distribution $F(\theta)$ with density $f(\theta)$ in $[0, \overline{\theta}]$. In contrast, $\widetilde{x}$ cannot be influenced by anyone and its realization is not revealed to anyone, including the bank, until $t = 1$. $\widetilde{x}$ has density $g(x)$ and distribution $G(x)$ in $[\underline{x}, \overline{x}]$, with $-\infty \leq \underline{x} < \overline{x} \leq \infty$. The interpretation is that, even after the bank observes its loan quality and thus resolves some uncertainty about loan risk, banking is risky.

At $t = 0$, after observing its loan quality θ, the bank makes its risk-taking decision $k(\theta)$. Conditional on its private information at $t = 0$, the bank's benefit of risk-taking is

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[7] The single loan is a stand-in for a large portfolio of loans, each with cash flow $\widetilde{\theta} + \widetilde{x} + \widetilde{\varepsilon}_n$, where $\widetilde{\theta} + \widetilde{x}$ and $\widetilde{\varepsilon}_n$ are the systematic and the idiosyncratic components of loan risk respectively, mutually independent and with zero mean except for $\widetilde{\theta}$. Thus, the aggregate cash flow of the loan portfolio is $\widetilde{\theta} + \widetilde{x} = \lim_{N \to \infty} \frac{1}{N} \sum_{n=1}^{N} \left(\widetilde{\theta} + \widetilde{x} + \widetilde{\varepsilon}_n \right)$.

the expected cash flow per unit of loan $E[\widetilde{\theta} + \widetilde{x}|\theta] = \theta$.[8] In addition, the bank also faces a convex cost $\frac{1}{2c}k\left(\theta\right)^2$ for risk-managing the loan, where c controls the cost sensitivity.[9] In the rest of the paper, I will use the terms risk-taking and risk retention interchangeably.

To motivate bank regulation, I assume that the risk-taking by a (type of) bank adversely affects other banks.[10] The negative aggregate externality in the banking sector, or systemic risk for short, is captured by

$$\int_0^{\overline{\theta}} K\left(\theta\right) f\left(\theta\right) d\theta, \tag{1}$$

where $K\left(\theta\right) = \int \xi\left(\omega, \theta\right) k\left(\theta\right) f\left(\omega\right) d\omega$ measures the contribution to the aggregate externality by the risk-taking of bank type θ, and $\xi\left(\omega, \theta\right) > 0$ is the per-unit externality of the risk-taking of bank type θ on bank type ω. Let $\kappa\left(\theta\right) \triangleq \int \xi\left(\omega, \theta\right) f\left(\omega\right) d\omega$. The greater the aggregate risk-taking in the banking sector $\{k\left(\theta\right)\}$, the greater the aggregate externality. Since θ is the only source of uncertainty about loan quality and severity of the externality, I refer to θ as the quality (type) of the bank. The value of the bank of type θ at $t = 0$ is then

$$U\left(k, \tau; \theta\right) = V\left(k; \theta\right) - \tau = \theta k - \tfrac{1}{2c}k^2 - \tau, \tag{2}$$

where $\tau \geq 0$ is a tax set by the regulator.[11] The bank values satisfy single-crossing

$$-\frac{\partial}{\partial \theta}\frac{U_k}{U_\tau} = V_{k\theta} > 0, \quad \text{for all } \theta, k, \tau.$$

In words, higher-quality banks benefit more (after tax) from risk-taking.

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[8] Alternatively, θ could reflect the privately known benefits of a risky loan to the bank protected by limited liability. Risk-taking by the bank is then influenced by the classic risk-shifting incentive.

[9] An alternative interpretation is a private risk-return tradeoff underlying the bank's risk-taking choice. With bank value being increasing in the average loan cashflow and decreasing in the total cashflow risk, bank value can be written $U = \mu\left(\theta\right) k - \frac{\sigma^2(\theta)}{2c}k^2$. The normalization to risk-adjusted expected return $h\left(\theta\right) = \frac{\mu(\theta)}{\sigma^2(\theta)}$ reconciles the bank value in the text for $h\left(\theta\right) = \theta$. The analysis relies on any increasing function h of risk-adjusted returns.

[10] See Greenwood, Landier, and Thesmar (2015) for sources of negative externalities in the banking sector.

[11] The interpretation of the tax is the incremental funding cost imposed on the bank in the case of capital regulation, and the risk assessment charged by the FDIC in the case of deposit insurance.

In designing the regulation $(k(\theta), \tau(\theta))$, the regulator's objective is to maximize social welfare at $t = 0$, the value of the banking sector plus total tax revenue with welfare weight $\lambda \in (0, 1)$, similar to Baron and Myerson (1982),

$$\int_0^{\overline{\theta}} \left[\, U(k, \tau; \theta) - \gamma K + \lambda \tau \,\right] f(\theta)\, d\theta.$$

where $\gamma > 0$ controls how costly systemic risk is to the banking sector.

3   Equilibrium

To illustrate the failure in the competitive market outcome and its regulatory solution, I first present the outcomes when bank quality is public information. This will serve as the benchmark for the analysis under asymmetric information about bank quality. The equilibrium concept is Perfect Bayesian Equilibrium. Hats denote quantities in the analysis under asymmetric information.

3.1   Risk-taking and regulation under full information

In the unregulated competitive equilibrium, defined as $\left(\{k^M(\theta)\}, K^M\right)$, banks choose their risk-taking ignoring the impact of their risk-taking k on the aggregate externality

$$\text{i)}\ k^M(\theta) = \arg\max_k \left\{\theta\, k - \frac{1}{2c} k^2\right\}\ \text{for all}\ \theta \in \left[0, \overline{\theta}\right],$$

$$\text{ii)}\ K^M = \int_0^{\overline{\theta}} \xi(\omega, \theta)\, k^M(\theta)\, f(\omega)\, d\omega.$$

Proposition 1. *In the unregulated competitive equilibrium under complete information, bank risk-taking is* $k^M(\theta) = c\,\theta$.

Trading off the benefits of risk-taking against its risk-management cost, the individual

bank chooses the size of its loan portfolio, which determines the privately optimal size of the bank. The collective risk-taking behavior of all banks taken together however produces the social cost from the aggregate externality. The resulting welfare loss from this market failure motivates the introduction of regulation.

In the regulator equilibrium, defined as $\left(\left\{k^R(\theta)\right\}, K^R\right)$, the regulator maximizes social welfare through the choice of banks' collective risk-taking

$$\left(\left\{k^R(\theta)\right\}, K^R\right) = \arg\max_{\left(\{k(\theta)\}, K\right)} \int_0^{\overline{\theta}} \left[\theta k(\theta) - \tfrac{1}{2c}k(\theta)^2 - \gamma K\right] f(\theta)\, d\theta$$

$$s.t. \quad K = \int_0^{\overline{\theta}} \xi(\omega, \theta)\, k(\theta)\, f(\omega)\, d\omega.$$

After substituting the aggregate externality into the objective function and changing the order of integration, the first-order condition to the program becomes

$$\theta = \tfrac{1}{c}k^R(\theta) + \gamma\kappa(\theta). \tag{3}$$

Proposition 2. *In the regulated equilibrium under full information, bank risk-taking is* $k^R(\theta) = c\left[\theta - \gamma\kappa(\theta)\right].$

The social optimum of risk-taking in the economy is reached where the marginal social benefit of risk-taking (the left-hand side of (3)) equals its marginal social cost (the right-hand side of (3)). When bank quality is public information, the regulator can exploit this information to perfectly and costlessly correct the market failure. The regulator chooses the banks' risk-taking on their behalf taking into account the impact of their collective behavior on the aggregate externality. As such, the regulator internalizes the externality in his choices.

3.2 Regulation under asymmetric information

Bank quality is now private information of the bank, its type. This information asymmetry between the bank and the regulator complicates the design of regulation. The regulator must elicit information from the bank to be able to use it in setting the regulation. To achieve this, the regulation needs to provide the bank with incentives to reveal its information and to subject itself to the regulation: regulation must be incentive compatible, reflected in constraints (4), and leave banking profitable, reflected in constraints (5).

Among all such feasible mechanisms, the optimal regulatory mechanism solves

$$\max_{k(\theta) \geq 0, \, \tau(\theta) \geq 0} \quad \int_0^{\overline{\theta}} \left[U\left(k\left(\theta\right), \tau\left(\theta\right); \theta\right) - \gamma K\left(\{k\left(\theta\right)\}\right) + \lambda \, \tau\left(\theta\right) \right] f\left(\theta\right) d\theta$$

$$s.t. \quad U\left(k\left(\theta\right), \tau\left(\theta\right); \theta\right) \geq U\left(k\left(\theta'\right), \tau\left(\theta'\right); \theta\right) \quad \text{for } \theta, \theta' \in \left[0, \overline{\theta}\right], \quad (4)$$

$$U\left(k\left(\theta\right), \tau\left(\theta\right); \theta\right) \geq 0 \quad \text{for } \theta \in \left[0, \overline{\theta}\right]. \quad (5)$$

This program can be simplified in a series of steps. The preference of higher-quality banks for higher risk-taking implies that, for banks to reveal themselves through their choice of risk-taking, risk-taking must be non-decreasing in θ. This allows me to replace the global incentive compatibility (IC) constraints in (4) with local IC constraints and a monotonicity constraint on risk-taking (Laffont and Maskin (1980))

$$\max_{\theta} U\left(k\left(\theta\right), \tau\left(\theta\right); s\right) \Big|_{s=\theta}, \quad (6)$$

$$k'\left(\theta\right) \geq 0. \quad (7)$$

Define the indirect bank value $U\left(\theta\right) \triangleq U\left(k\left(\theta\right), \tau\left(\theta\right); \theta\right)$. Differentiating the indirect bank value, and using the envelope theorem with (6), gives $U'\left(\theta\right) = U_\theta\left(k\left(\theta\right), \tau\left(\theta\right); \theta\right) = V_\theta\left(k\left(\theta\right); \theta\right)$. Once optimal risk-taking is determined, the bank's indirect value is obtained by integration as $U\left(\theta\right) = U\left(0\right) + \int_0^{\theta} V_\theta\left(k\left(s\right); s\right) ds$, where $U\left(0\right) = 0$.[12] Rearranging the

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[12] To see this, note that, since taxes must be non-negative, constraints (5) impose that regulated banking

indirect bank value gives the optimal tax

$$\tau(\theta) = V(k(\theta);\theta) - \int_0^\theta V_\theta(k(s);s)\,ds. \tag{8}$$

Intuitively, the optimal tax is set so as to charge the bank for revealing itself through its risk-taking.

By substituting out the tax and simplifying, we can rewrite social welfare as

$$\max_{k(\theta)\geq 0} \int_0^{\bar\theta} \left[V(k(\theta);\theta) - (1-\lambda)\left(V(k(\theta);\theta) - \int_0^\theta V_\theta(k(s);s)\,ds \right) - \gamma K(\theta) \right] f(\theta)\,d\theta$$

$$= \max_{k(\theta)\geq 0} \int_0^{\bar\theta} \left[\lambda V(k(\theta);\theta) + (1-\lambda) V_\theta(k(\theta);\theta) \frac{1-F(\theta)}{f(\theta)} - \gamma K(\theta) \right] f(\theta)\,d\theta, \tag{9}$$

where the equality follows from standard integration by parts. The regulator's simplified objective function is the sum of the bank's so-called virtual surplus less the aggregate externality. The second term reflects the incentives for information revelation. Optimal risk-taking is now solution to maximizing social welfare subject to risk-taking being non-decreasing. I will solve the so-called relaxed problem in (9) without the monotonicity constraint (7), and then check whether the constraint is satisfied at the solution. The first-order condition of the relaxed program is

$$Y_k(k^*(\theta);\theta) \triangleq \lambda V_k(k^*(\theta);\theta) + (1-\lambda) V_{\theta k}(k^*(\theta);\theta) \frac{1-F(\theta)}{f(\theta)} - \gamma K_k(\theta) = 0. \tag{10}$$

Implicitly differentiating this condition gives

$$\frac{dk^*(\theta)}{d\theta} = -\frac{Y_{k\theta}(k^*(\theta);\theta)}{Y_{kk}(k^*(\theta);\theta)}. \tag{11}$$

The second-order condition for a maximum, $Y_{kk} < 0$, implies that the sign of $Y_{k\theta}(k^*(\theta);\theta)$

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be profitable. Then, there exists a break-even threshold of quality $\underline\theta$ below which regulated banking is unprofitable, characterized by $V(k^*(\underline\theta);\underline\theta) = 0$. As a result, any type θ in $[0,\underline\theta]$ will not participate in banking (that is, not engage in risk-taking and not be taxed), that is $k^*(\theta) = \tau^*(\theta) = 0$, and thus obtain zero value, that is $V(k^*(\theta);\theta) = 0$. Thus, $U(\theta) = 0$ for $\theta \in [0,\underline\theta]$.

determines the sign of $\frac{d}{d\theta} k^*(\theta)$. Expanding the numerator gives

$$Y_{k\theta} = \lambda V_{k\theta} + (1 - \lambda) V_{\theta k} \left[\frac{1 - F(\theta)}{f(\theta)} \right]' + (1 - \lambda) V_{\theta\theta k} \frac{1 - F(\theta)}{f(\theta)} - \gamma K_{k\theta}$$

$$= \lambda \left[v'(\theta) V_{k\theta} - e'(\theta) \right]. \tag{12}$$

where $v'(\theta) \triangleq 1 + \left(\frac{1-\lambda}{\lambda} \right) \left[\frac{1-F(\theta)}{f(\theta)} \right]'$ is the marginal virtual value of the bank, and $e'(\theta) \triangleq \frac{\gamma}{\lambda} K_{k\theta}$ is the change in the marginal contribution to the externality by bank type θ. Thus, expression (12) reveals that, with single-crossing $V_{k\theta} > 0$, an increasing marginal virtual bank value is a necessary (but not sufficient) condition for $k^*(\theta)$ to be non-decreasing - in contrast to the classic mechanism design problem. For risk-taking to be non-decreasing in the design of an optimal mechanism with externalities (from screening), the marginal social surplus of bank risk-taking must be higher for higher bank types, that is $Y_{k\theta} > 0$ for all θ.

When $Y_{k\theta}$ is not increasing for all bank types, risk-taking is not always increasing. As a result, the monotonicity constraint on risk-taking will bind for some bank types. Optimal risk-taking is then "ironed" out across some bank types resulting in pooling or bunching regions. In general, there can exist multiple such pooling intervals. Guesnerie and Laffont (1984) show how bunching can occur in classic mechanism design problems. The following lemma highlights a necessary condition for the existence of pooling in the design of mechanisms with externalities (from screening).

Lemma 1. *(Bunching) Given increasing marginal virtual bank values, heterogeneity of the externality in bank quality is a necessary condition for bunching in bank regulation under asymmetric information.*

Expression (11) shows that risk-taking is decreasing for some levels of bank quality when the marginal social surplus is decreasing in bank quality in those intervals. From expression (12), it is straightforward to see that a necessary condition for this is that the contribution to the aggregate externality depends on bank quality.

Proposition 3 below illustrates the general analysis of optimal mechanisms with externalities (from screening). The solution to the regulator problem with a binding monotonicity constraint at the top of the bank-quality distribution is determined as follows[13]

$$\max_{k(\theta), \overline{k}, \widehat{\theta}} \int_0^{\widehat{\theta}} Y\left(k\left(\theta\right); \theta\right) f\left(\theta\right) d\theta + \int_{\widehat{\theta}}^{\overline{\theta}} Y\left(\overline{k}; \theta\right) f\left(\theta\right) d\theta.$$

subject to the monotonicity constraint (7). Optimal risk-taking for any bank type $\theta \in [\widehat{\theta}, \overline{\theta}]$ is determined by the pooling interval $[\widehat{\theta}, \overline{\theta}]$ and the pooled level of risk-taking $\overline{k}$, jointly characterized by the following two conditions

$$k^*(\widehat{\theta}) = \overline{k}, \tag{13}$$

$$\int_{\widehat{\theta}}^{\overline{\theta}} Y_k\left(\overline{k}; \theta\right) f\left(\theta\right) d\theta = 0. \tag{14}$$

The first condition imposes that at the starting point of the bunching interval the separating level of risk-taking k^* coincide with the pooled level $\overline{k}$. The second condition shows that the pooling interval is determined so that the marginal social surplus from risk-taking $\overline{k}$ averages to zero over this interval.

4 Analysis

In this section, I will illustrate the general analysis of the preceding section with the following simple structure of bank quality, which I maintain in the rest of the paper.

Assumption. (Bank quality) *Bank quality is uniformly distributed, $\theta \overset{f}{\sim} U\left[0, \overline{\theta}\right]$, the externality is quadratic, $\xi = 2\omega\left(\frac{\theta}{\overline{\theta}}\right)^2$, banking is moderately important, $\lambda \in \left(\underline{\lambda}, \overline{\lambda}\right)$, and not too sensitive to the externality, $\gamma < \frac{1}{2}$.*

This structure of bank quality ensures a closed-form solution to the optimal regulation problem under asymmetric information, stated in Proposition 3 and depicted in Figure 1.

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[13] An alternative proof based on optimal control theory is included in the Appendix.

Proposition 3. *(Optimal regulation)* *When bank quality is private information of the bank, regulated risk-taking and taxes are*

$$
\widehat{k}^{R}(\theta) = \begin{cases} 0, & for\ \theta \in [\,0,\underline{\theta}\,) \\[2mm] c\,[\,v\,(\theta)-e\,(\theta)\,], & for\ \theta \in \left[\underline{\theta},\widehat{\theta}\,\right), \\[2mm] \overline{k}, & for\ \theta \in \left[\widehat{\theta},\overline{\theta}\,\right] \end{cases}
$$

$$
\widehat{\tau}^{R}(\theta) = \begin{cases} 0, & for\ \theta \in [\,0,\underline{\theta}\,) \\[3mm] c\,[\,v\,(\theta)-e\,(\theta)\,]\left[\,\theta-\tfrac{1}{2}\,(v\,(\theta)-e\,(\theta))\,\right] \\ \quad -c\displaystyle\int_{\underline{\theta}}^{\theta}[\,v\,(s)-e\,(s)\,]\,ds, & for\ \theta \in \left[\underline{\theta},\widehat{\theta}\,\right) \\[3mm] \widehat{\theta}\,\overline{k}-\tfrac{1}{2c}\overline{k}^{2}-c\displaystyle\int_{\underline{\theta}}^{\widehat{\theta}}[\,v\,(s)-e\,(s)\,]\,ds, & for\ \theta \in \left[\widehat{\theta},\overline{\theta}\,\right] \end{cases}
$$

where $\underline{\theta} = \left[\frac{\sqrt{4\gamma(1-\lambda)+1}-1}{2\gamma}\right]\overline{\theta}$, $\widehat{\theta} = \left[\frac{3(2\lambda-1)-2\gamma}{4\gamma}\right]\overline{\theta}$, $\overline{k} = c\left[\frac{3(2\lambda-1)^{2}-4\gamma(2\lambda-3-\gamma)}{16\lambda\gamma}\right]\overline{\theta}$, $v\,(\theta) = \theta+\frac{1-\lambda}{\lambda}\left(\overline{\theta}-\theta\right)$ *and* $e\,(\theta) = \frac{\gamma\theta^{2}}{\lambda\overline{\theta}}$. *Also,* $k^{*}(\theta) = c\,[\,v\,(\theta)-e\,(\theta)\,]$.
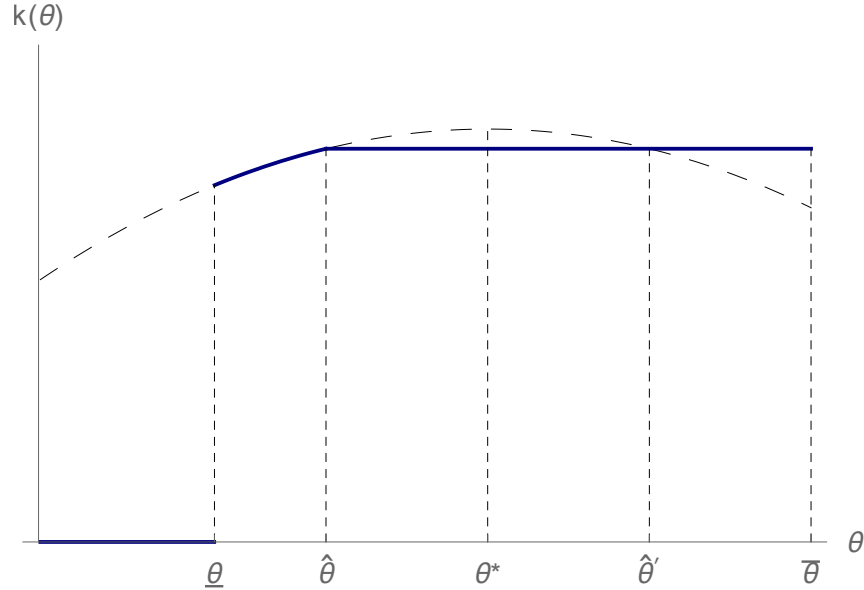

Figure 1: Regulated risk-taking. The figure plots regulated risk-taking under asymmetric information, $\widehat{k}^{R}(\theta)$ and $k^{*}(\theta)$. Parameter values are $\overline{\theta} = 4.2$, $\gamma = 0.43$, $\lambda = 0.75$, $c = 1$.

The salient feature of Proposition 3 is that private incentives for information production exist (single-crossing holds). Yet, Proposition 3 shows that information production is limited - despite incentives to supply information being perfect.

The intuition is simple. Producing information requires incentives to both supply and demand this information. Banks can supply information to the regulator through their risk-taking. Supplying information to the regulator then requires that a higher-quality bank retain more risk (the monotonicity constraint (7)). Intuitively, a higher-quality bank derives greater benefits from risk-taking and thus reveals itself through higher risk-taking. However, even though the potential *supply* of information by banks thus exists (equivalently, the *ability* by the regulator to elicit information from banks), the *demand* for this information does not always. A case in point is the interval $[\widehat{\theta}, \theta^*]$ in Figure 1. This interval contains bank types that are willing to supply information (whose (dotted-lined) risk-taking is increasing). Yet, the regulator chooses not to demand this information ((thick-lined) risk-taking is constant). The reason the regulator does not always choose to elicit the information is because doing so would distort the allocation of risk (taking). From Proposition 3, the distortion of risk-taking (relative to the complete information market outcome) has two components. To see this, rewrite the first-order condition (10) as

$$\theta + \underbrace{\frac{1-\lambda}{\lambda} \frac{1-F(\theta)}{f(\theta)}}_{\text{"skin in the game"}} = \frac{k^*(\theta)}{c} + \frac{\gamma}{\lambda} \kappa(\theta). \qquad (15)$$

Optimal regulation balances the (marginal) social benefits of risk-taking, the left-hand side of (15), with its (marginal) social costs, the right-hand side. The two distortions to bank risk-taking are captured in the last term on either side. The last term on the LHS reflects an upward distortion in the risk-taking by bank type θ to achieve information revelation. The interpretation is that the regulation requires the bank to retain excessive risk ("skin in the game") to separate itself from other bank types. The last term on

the RHS captures a downward distortion in bank θ's risk-taking due to its contribution to the aggregate externality. Relative to the regulatory outcome under full information characterized by (3), the bank takes additional risk to convey its riskiness to the regulator but in so doing exacerbates the market failure that motivates the regulation. This illustrates a new tension between the informational and the allocative efficiency that complicates the design of regulation under asymmetric information: the micro-economic role of risk retention (information production) conflicts with its macro-economic consequences (negative externalities).

4.1   Risk-insensitivity and risk weights

When the marginal social costs of risk-taking increase faster than the marginal social benefits as bank quality increases, risk-taking by higher-quality banks becomes less socially desirable. Beyond some peak level of bank quality θ^* (see Figure 1), the socially optimal level of risk-taking starts to fall. If the regulator were privy to bank quality, the social net benefits of the risk allocation would determine the optimal risk-taking by banks. However, the information about bank quality is not freely available, and the regulator needs to rely on bank risk-taking to infer bank quality. Such incentive compatible allocations of risk, which would allow the regulator to learn about bank quality, require that higher-quality banks take more risk (risk-taking must be non-decreasing in bank quality). However, the pursuit of achieving the socially optimal allocation of risk forces two bank types to hold the same level of risk, captured by bank types $\widehat{\theta}$ and $\widehat{\theta}'$ in Figure 1 for example, thereby making it impossible for the regulator to infer bank quality from that level of risk $\widehat{k}^R(\widehat{\theta}) = \widehat{k}^R(\widehat{\theta}')$. The regulation becomes insensitive to the very risk it seeks to control.

Corollary 1. *(**Risk-insensitive regulation**) When bank quality is private information of the bank and the externality is quadratic, regulation is risk-insensitive for high bank types $\theta \in [\widehat{\theta}, \overline{\theta}]$. Only risk-insensitive regulation necessitates a system-wide approach.*

Corollary 1 highlights the extreme downside of risk-sensitive regulation. When banks with higher-quality loans (high expected cash flow) are also the ones whose risk-taking causes greater social harm (large externality), the regulator chooses not to make the regulation sensitive to the risk of these banks. That is, when the social benefits and the social costs from risk-taking are positively correlated but the social surplus (the difference) decreases with bank quality (as is the case with a quadratic externality), regulation becomes risk-insensitive at the top of the bank-quality distribution. The assumption that larger banks (from (7), risk-taking is (weakly) increasing in θ) are the bigger troublemakers for the system is consistent with the concept of "systemically important financial institutions", a recent regulatory development in the U.S. (see footnote 4).

Risk-insensitivity of the regulation manifests in the interval $[\widehat{\theta}, \overline{\theta}]$, in which both risk-taking and the tax are independent of bank quality θ. The economic implication is that, in the pooling interval, the optimal tax is constant, as can be seen from (6): $\widehat{\tau}^R(\theta)' = V_k \widehat{k}^R(\theta)' = 0$ for $\theta \in [\widehat{\theta}, \overline{\theta}]$. In words, revealing no additional information is free. The constant tax resembles the use of the same risk weight for a bucket of risky assets (bank types in $[\widehat{\theta}, \overline{\theta}]$), much like in the Basel bank capital regulations. A generalization of Proposition 3 shows that, when the severity of externality varies strongly with bank quality θ, the optimal regulation features multiple risk buckets, each endowed with a progressively higher tax. This feature seems to fit real-world bank capital regulation quite well.

Moreover, the analysis reveals that only risk-insensitive regulation necessitates a system-wide approach. The design of regulation requires information. When the regulation is risk-sensitive, the only type of information required is information about the contribution of the individual bank's risk-taking to the value of the banking system. In contrast, risk-insensitive regulation relies on information about all banks that are subject to risk-insensitive regulation, that is all bank types in the bunching interval as apparent from condition (14).

Proposition 3 showed that the regulation forces the bank to retain "skin in the game" to convey the private information about its risk to the regulator. The following lemma states that, as the information asymmetry increases, so does its solution (skin in the game). Figure 2 illustrates.

Lemma 2. *(Information asymmetry and risk-taking) The risk-taking of the regulated bank increases with the degree of information asymmetry, that is $\frac{\partial}{\partial \overline{\theta}} \widehat{k}^R(\theta) > 0$ for $\theta \in [\underline{\theta}, \overline{\theta}]$.*

This prediction is reminiscent of the solution to the information asymmetry in the classic adverse selection problem (e.g. Leland and Pyle (1977)). When the regulator needs to distinguish between a greater number of bank types, the regulation forces each type of bank to hold more risk. This is intuitive for the risk-sensitive interval of the regulation from the classic adverse selection problem. However, this is also true for bank types in the risk-insensitive interval in my model. The reason is that as the information asymmetry increases so does the threshold level of bank quality above which the regulation becomes risk-insensitive.

However, as the information asymmetry and its solution (skin in the game) increase, the regulation also uses less information. That is, the (relative) length of the risk-insensitive interval $\frac{\overline{\theta} - \widehat{\theta}}{\overline{\theta}}$ increases with the degree of information asymmetry. This paradoxical result is stated in Lemma 3 and depicted in Figure 2.

Lemma 3. *(Market frictions and risk-insensitivity) The regulation becomes more insensitive to bank risk when the informational friction is more severe, that is $\frac{\partial}{\partial \overline{\theta}} \frac{\overline{\theta} - \widehat{\theta}(\overline{\theta})}{\overline{\theta}} > 0$, and systemic risk is costlier, that is $\frac{\partial}{\partial \gamma} \frac{\overline{\theta} - \widehat{\theta}(\gamma)}{\overline{\theta}} > 0$.*

The intuition is simple. Information asymmetry increases as the number of bank types $\overline{\theta}$ (equivalently the interval $[0, \overline{\theta}]$) that the regulator needs to distinguish expands. This creates a tension. On the one hand, to overcome this growing information asymmetry and differentiate between more bank types, the regulator forces the bank to increase its skin in
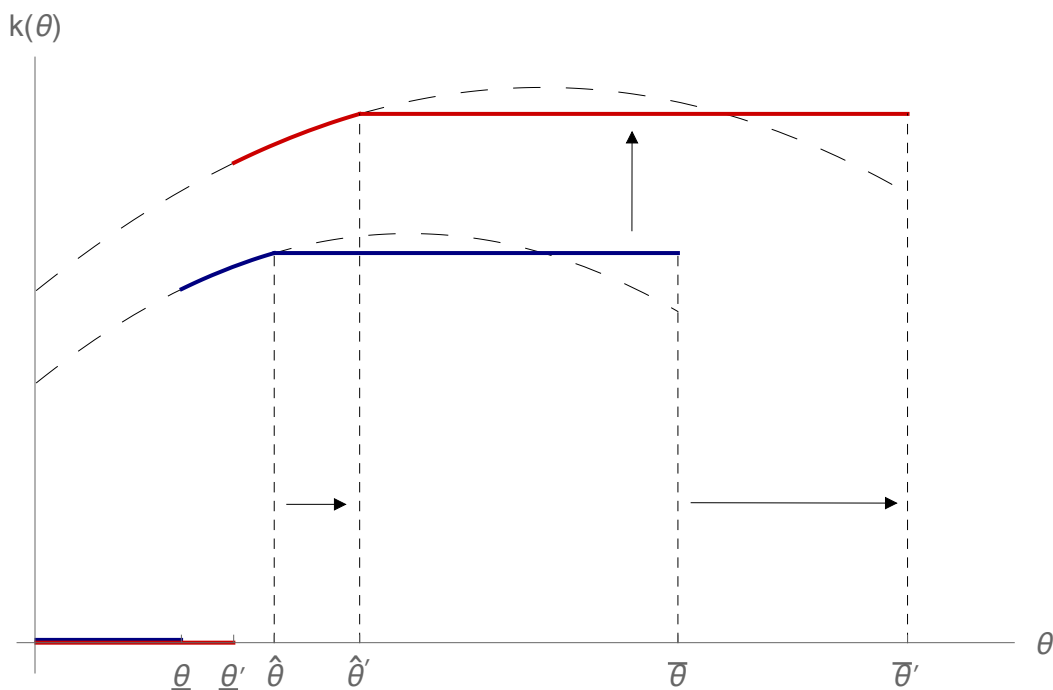
Figure 2: Regulated risk-taking under increasing information asymmetry. The figure plots levels of regulated risk-taking $\widehat{k}^R(\theta)$ under two values of the information asymmetry parameter $\overline{\theta}$ ($\overline{\theta} = 4.2$ (blue), $\overline{\theta}' = 5.7$ (red)). Other parameter values are $\gamma = 0.43$, $\lambda = 0.75$, $c = 1$.

the game. On the other hand, the additional bank types cause ever greater social harm as the externality from their risk-taking is higher. The regulator responds to the increase in information asymmetry by expanding the bunching interval $[\widehat{\theta}, \overline{\theta}]$, thus suppressing information. Formally, as $\overline{\theta}$ increases, the threshold $\widehat{\theta}(\overline{\theta})$ increases at a lower rate than the upper bound $\overline{\theta}$.

Similarly, the degree of social cost also renders the regulation less risk-sensitive. γ controls how harmful the externality is to the banking system and thus the speed at which risk-taking reduces social surplus as bank quality θ increases. A higher γ reduces social surplus faster making risk-taking less socially desirable. Regulation discourages such risk-taking by pushing down the threshold of the bunching interval, thereby enlarging it.
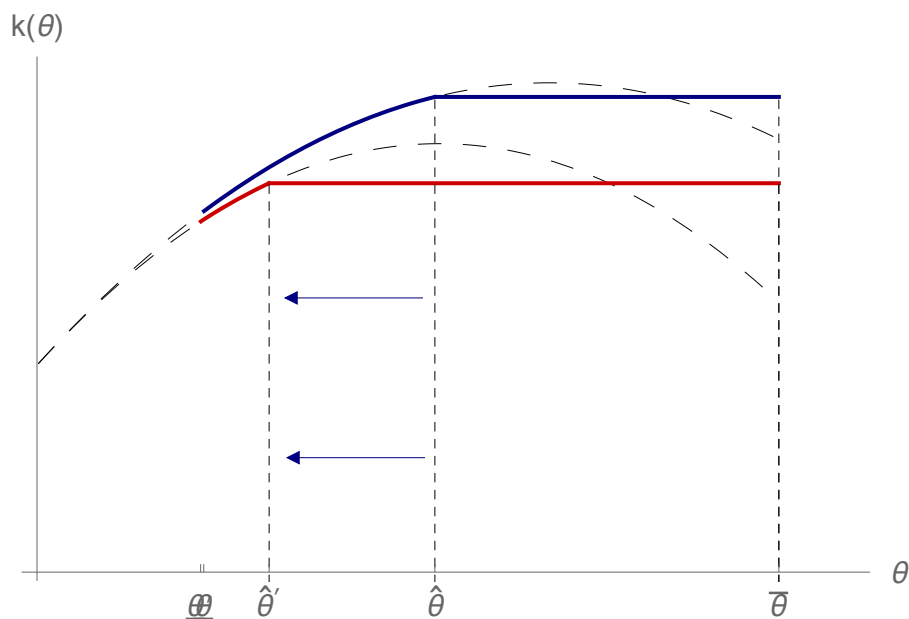
Figure 3: Regulated risk-taking under increasing social cost. The figure plots levels of regulated risk-taking $\widehat{k}^R(\theta)$ under two values of the social cost parameter γ ($\gamma = 0.33$ (blue), $\gamma' = 0.43$ (red)). Other parameter values are $\overline{\theta} = 4.2$, $\lambda = 0.75$, $c = 1$.

In sum, as the market frictions (of information asymmetry, measured by an increase in $\overline{\theta}$, and the cost of the allocative externality, measured by γ) become more severe, the regulation becomes less sensitive to the very market failure (systemic risk) it seeks to control.

5   Discussion

In this section, I discuss the empirical relevance of the mechanism and two policy implications of my theory.

5.1 "Skin in the game" risk retention[14]

The incentives of financial intermediaries were at the center of the debate about the causes and fixes of the crisis. One solution to align incentives and overcome market imperfections is market participants holding "skin in the game", the inefficient excessive retention of risk. Such retention of residual interests in transactions could convey the quality of the transaction to the counterparty, and thus overcome the market failure from adverse selection.

While it is still debated whether "skin in the game" actually worked as intended, there is both theoretical and empirical support for this assumption. Retaining partial interests by the bank could be a solution to both its information advantage over investors or its unobservable incentive to improve the value of loans (e.g. Leland and Pyle (1977); Gorton and Pennacchi (1995); DeMarzo and Duffie (1999); Fender and Mitchell (2009); Chemla and Hennessy (2014); Vanasco (ming)). There is also empirical evidence indicating that banks do have private information and use retention as a signal (e.g. Simons (1993); Higgins and Mason (2004); Sufi (2007); Keys, Mukherjee, Seru, and Vig (2009); Acharya and Schnabl (2010); Loutskina and Strahan (2011); Erel, Nadauld, and Stulz (2014); Ashcraft, Gooriah, and Kermani (2014)). Acharya and Schnabl (2010) presents evidence that banks were exposed to the risk of their transferred assets ex post through investor recourse, consistent with the "skin in the game" mechanism. Higgins and Mason (2004) finds similar results and additionally shows that the recourse to sponsors of structuring transactions improved the long-run operating performance of sponsors as well as their stock prices in the short and long run following recourse events.

Retention is typically a large component on a bank's balance sheet and exerts important influences on a bank's income statement. Using the data from regulatory filings (e.g. schedules HC-S in Y-9C and RC-S in Call Reports) that U.S. bank holding companies file quarterly with the Federal Reserve, Chen, Liu, and Ryan (2008) report that on average

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[14]The discussion is inspired by Bleck and Gao (2015).

the value of interest-only strips and subordinated asset-backed securities, two components of retention, accounts for about 11% of the outstanding principal balance of private label securitized loans. The information about a bank's position in retention interest is also available from SEC filings (e.g. 10-Q and 10-K) if the position is material.

5.2   Macro-prudential regulation

My theory applies to macro-prudential regulations of financial institutions, that is any regulation designed to reduce negative externalities, most directly in the financial sector. The most notable example is bank capital regulation known as the Basel Accords promulgated by the Bank for International Settlements (BIS). In particular, in its latest accord known as Basel III, the BIS introduced additional capital regulations to target institutions whose activities are most likely to cause (greater) negative externalities, so-called systemically important financial institutions (SIFIs), including non-bank financial institutions.[15]   In addition, the Financial Stability Board (FSB), an international body of finance ministers and central bankers, monitors SIFIs as part of its goal of promoting financial stability.[16]

A key feature of capital regulation is its risk-sensitivity. Conventional wisdom holds that efficient regulation should exploit all relevant information in its design. Put differently, regulation should reflect and be sensitive to the risk it seeks to control. Yet, a glance at the evolution of capital regulation offers a puzzle. The first such accord known as Basel I, introduced in 1989, allocated risks into buckets with varying capital charges. Accordingly, any two risky assets in the same bucket received the same charge. This crudeness in reflecting risk motivated the 1996 Basel II Accord to refine "risk-sensitivity" and improve "incentive compatibility" of the regulation (BIS (2001, p.1)). The Accord was designed to achieve this by offering an alternative approach to the bank by which it exploits its own

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[15] See BIS release http://www.bis.org/publ/bcbs207.htm.

[16] See FSB releases http://www.fsb.org/wp-content/uploads/Policy-Measures-to-Address-Systemically-Important-Financial-Institutions.pdf and http://www.fsb.org/wp-content/uploads/r_101111a.pdf.

information in setting risk charges. The puzzling empirical relationship between measured (regulated) risk and realized risk in the aftermath of Basel II led policymakers to question the effectiveness of this approach, and its inherent conflict of interest. Van Hoose (2007); Haldane (2013) and Acharya, Engle, and Pierret (2014) note that risk-sensitive measures were poor predictors of actual risk, and no better than risk-insensitive alternatives. Begley, Purnanandam, and Zheng (2016) finds that banks underreport their actual risk while Behn, Haselmann, and Vig (2014) and Becker and Opp (2014) show that risk-sensitive regulation actually increased risk in banks and insurance companies, respectively. In response to this counterproductive effect of risk-sensitive regulation on risk-taking experienced around the recent Financial Crisis, the BIS is working on amending its standards toward lower risk-sensitivity.[17]

My theory provides an explanation for the risk-insensitivity of observed capital regulation, and its counterproductive effects in Haldane (2013); Behn, Haselmann, and Vig (2014); Becker and Opp (2014). Eliciting information from banks to set regulation forces banks to retain excessive risk, thereby exacerbating the very market failure the regulation seeks to correct. Optimal regulation becomes risk-insensitive when the social cost from such skin-in-the-game becomes excessive.

5.3 Micro- in conflict with macro-prudential regulation

My theory also offers a caveat for the coherent design of bank regulation. Financial regulation comes in two forms: micro-prudential (aimed at the soundness of the individual institution) and macro-prudential (aimed at the soundness of the system as a whole). The distinction was first highlighted by Crockett (2000) and Hansen, Kashyap, and Stein (2011). In similar spirit to Morris and Shin (2008) albeit with a different mechanism, I argue that these regulations could be in conflict: attempting to reduce the fragility of the individual

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[17]See https://www.bis.org/speeches/sp151010.htm and https://www.bis.org/press/p160324.htm.

institution could exacerbate the instability of the system.

In response to the recent Financial Crisis, regulators in the U.S. and Europe have adopted micro-prudential regulations to require minimum risk retention by various financial institutions. The most prominent example is the 2010 Dodd-Frank Act in the U.S., which has been adopted by virtually all U.S. financial agencies,[18] and the Capital Requirements Regulation in Europe.[19] The regulation received support from then U.S. Secretary of Treasury Tim Geithner, in his role as the chairman of the Financial Stability Oversight Council, who highlighted the "macro-economic effects of risk retention requirements".[20]

The caveat my theory offers is simple. Risk retention could improve the individual institution but destabilize the collective. The micro-economic rationale for risk retention is to overcome conflicts of interest arising from informational frictions that harm the individual institution. For example, minimum risk retention by the bank could improve its origination incentives leading to higher loan quality and a more stable bank. The macro-economic consequence of risk retention is the negative externality such risk poses to the financial system. When every bank is required to hold minimum risk from its loan originations, the banking system as a whole is more susceptible to systemic fragility. The tradeoff in my theory revolves precisely around these two factors and demonstrates a limit to the use of risk retention as a solution to market frictions.

6   Conclusion

In this paper, I study the design of bank regulation to explain the puzzling observation that bank regulation is surprisingly not all that risk-sensitive in practice. The paper points out a conceptual shortcoming to setting risk-sensitive regulation. Eliciting information

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[18] http://www.sfindustry.org/images/uploads/pdfs/Risk_Retention_Final_Rule.pdf

[19] https://www.eba.europa.eu/documents/10180/534414/Securitisation+Risk+Retention+Report.pdf

[20] https://www.treasury.gov/press-center/press-releases/Pages/tg1027.aspx

required to design risk-sensitive regulation affects the behavior of the regulated bank, in a manner similar to "regulatory arbitrage". Anticipating its treatment by the regulator, the bank engages in impressing the regulator (to pass the test) by increasing its risk-taking. That is, the response by the individual bank to the regulation could exacerbate the very market failure that motivates the regulation of the system. As a result, the cost of this feedback could be so large so as to discourage the regulator from screening the bank for information in the first place.

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A   Appendix

Proof of Proposition 3 The proof is broken into three parts: the proofs of the exclusion, the pooling and the separating regions.

The exclusion region $[0, \underline{\theta}]$ is characterized by the threshold $\underline{\theta}$, which is implicitly given by the bank's break-even condition $V\left(k^*\left(\underline{\theta}\right); \underline{\theta}\right) = 0$. Substituting for $k^*\left(\underline{\theta}\right)$ from (15) into this condition and simplifying shows that the threshold $\underline{\theta}$ is the positive solution to $\underline{\theta}^2 + \frac{\bar{\theta}}{\gamma}\underline{\theta} - (1-\lambda)\frac{\bar{\theta}^2}{\gamma} = 0$, or $\underline{\theta} = \left[\sqrt{4\gamma(1-\lambda)+1} - 1\right]\frac{\bar{\theta}}{2\gamma}$. Thus, set $\widehat{k}^R(\theta) = 0$ for $\theta \in [0, \underline{\theta}]$.

The pooling region $[\widehat{\theta}, \bar{\theta}]$ is characterized by the threshold $\widehat{\theta}$ that, together with the pooling level $\bar{k}$, is solution to conditions (13) and (14). Substituting for $k^*(\theta)$ evaluated at $\theta = \widehat{\theta}$ in condition (13) gives $c\left[\widehat{\theta} + \frac{1-\lambda}{\lambda}\left(\bar{\theta} - \widehat{\theta}\right) - \frac{\gamma}{\lambda}K_k\right] = \bar{k}$. Condition (14) gives $\int_{\widehat{\theta}}^{\bar{\theta}}\left[\lambda\left(\theta - \frac{\bar{k}}{c}\right) + (1-\lambda)\left(\bar{\theta} - \theta\right) - \gamma K_k\right]\frac{1}{\bar{\theta}}d\theta = 0$. Solving these two equations for $(\bar{k}, \widehat{\theta})$ gives the result in the Proposition. Thus, set $\widehat{k}^R(\theta) = \bar{k}$ for $\theta \in [\widehat{\theta}, \bar{\theta}]$.

The separating region follows from the previous result. In $[\underline{\theta}, \widehat{\theta}]$, $k^*(\theta)$ is non-decreasing and so the optimal risk-taking is solution to condition (10). The second-order condition is negative, that is $Y_{kk} = -\frac{\lambda}{c} < 0$, so the first-order condition gives a maximum. Thus, set $\widehat{k}^R(\theta) = k^*(\theta)$ for $\theta \in [\underline{\theta}, \widehat{\theta}]$.

The restriction $\lambda \in (\widehat{\lambda}, \bar{\lambda}) = (\frac{1}{2} + \frac{1}{3}\gamma, \frac{1}{2} + \gamma)$ ensures the existence of the pooling interval, that is $\widehat{\theta} \in [0, \bar{\theta}]$. The restriction $\gamma < \frac{1}{2}$ is a sufficient condition for $(\widehat{\lambda}, \bar{\lambda}) \subset (0, 1)$. I restrict λ to lie in a smaller interval $(\underline{\lambda}, \bar{\lambda})$, where $\underline{\lambda}, \underline{\lambda} > \widehat{\lambda}$, is given in the proof of Proposition 3.

An alternative, unifying proof of the separating and bunching solutions is based on optimal control theory. The control problem is defined by the Hamiltonian

$$H = Y\left(k\left(\theta\right), \tau\left(\theta\right); \theta\right)f\left(\theta\right) + \alpha\left(\theta\right)V_k\left(k\left(\theta\right); \theta\right)q\left(\theta\right) + \beta\left(\theta\right)q\left(\theta\right),$$

where $Y = V\left(k\left(\theta\right); \theta\right) - \tau\left(\theta\right) - \gamma K\left(\{k\left(\theta\right)\}\right) + \lambda\tau\left(\theta\right)$ is social welfare, $\tau'\left(\theta\right) = V_k\left(k\left(\theta\right); \theta\right)q\left(\theta\right)$ follows from incentive compatibility (6), with $q\left(\theta\right) = k'\left(\theta\right)$, and $q\left(\theta\right) \geq 0$ from the monotonicity constraint (7). This is a classical non-autonomous control problem with free boundaries and an inequality constraint on the control ($q\left(\theta\right)$ is the control variable and

$\tau(\theta)$ and $k(\theta)$ are the costate variables). The Pontryagin maximum principle provides the necessary and sufficient conditions for a solution

$$\frac{\partial H}{\partial q} = 0 \iff \alpha(\theta) V_k + \beta(\theta) = 0, \tag{16}$$

$$\frac{\partial H}{\partial \tau} = -\alpha'(\theta) \iff Y_t f(\theta) = -\alpha'(\theta), \tag{17}$$

$$\frac{\partial H}{\partial k} = -\beta'(\theta) \iff Y_k f(\theta) + \alpha(\theta) V_{kk} q(\theta) = -\beta'(\theta), \tag{18}$$

and the transversality conditions $\alpha(\overline{\theta}) = \alpha(0) = \beta(\overline{\theta}) = \beta(0) = 0$. Condition (17) along with the transversality condition implies

$$\alpha(\theta) = Y_\tau (1 - F(\theta)). \tag{19}$$

Substituting (19) into condition (16) gives

$$\beta(\theta) = -Y_\tau V_k (1 - F(\theta)). \tag{20}$$

When the monotonicity constraint is binding, $q(\theta) = 0$ and we have from condition (18)

$$Y_k f(\theta) + \beta'(\theta) = 0$$

$$\iff (V_k - \gamma K_k) f(\theta) - Y_\tau \frac{d}{d\theta} [V_k (1 - F(\theta))] = 0$$

$$\iff (V_k - \gamma K_k) f(\theta) + (1 - \lambda) \left[(1 - F(\theta)) \frac{d}{d\theta} V_k - f(\theta) V_k \right] = 0$$

$$\iff \left[\lambda \left(\theta - \frac{k(\theta)}{c} \right) + (1 - \lambda) \frac{1 - F(\theta)}{f(\theta)} \left(1 - \frac{q(\theta)}{c} \right) - \gamma K_k \right] f(\theta) = 0, \tag{21}$$

where in the last equality I used the definitions of V and K from (2) and (1).

Note that in the set in which the monotonicity constraint is binding, call it $[\widehat{\theta}, \overline{\theta}]$, we have for all θ in $[\widehat{\theta}, \overline{\theta}]$ $q(\theta) = k'(\theta) = 0$ and thus $k(\theta) = \overline{k}$, a constant. Integrating condition (21) over this set, we obtain the solution of the pooling region defined by the

following two conditions

$$\int_{\widehat{\theta}}^{\overline{\theta}} \left[\lambda \left(\theta - \frac{\overline{k}}{c} \right) + (1 - \lambda) \frac{1 - F(\theta)}{f(\theta)} - \gamma K_k \right] f(\theta) \, d\theta = 0,$$

$$k(\widehat{\theta}) = \overline{k}.$$

When the monotonicity constraint is not binding on some interval, that is when $q(\theta) > 0$, condition (18) with expressions (19) and (20) gives

$$
\begin{aligned}
0 &= Y_k f(\theta) + Y_\tau (1 - F(\theta)) V_{kk} q(\theta) - Y_\tau \frac{d}{d\theta} [V_k (1 - F(\theta))] \\
\Leftrightarrow 0 &= (V_k - \gamma K_k) f(\theta) + Y_\tau (1 - F(\theta)) V_{kk} q(\theta) - Y_\tau \left[(1 - F(\theta)) \frac{d}{d\theta} V_k - f(\theta) V_k \right] \\
\Leftrightarrow 0 &= ((1 + Y_\tau) V_k - \gamma K_k) f(\theta) + Y_\tau (1 - F(\theta)) \left[V_{kk} q(\theta) - \frac{d}{d\theta} V_k \right] \\
\Leftrightarrow 0 &= ((1 + Y_\tau) V_k - \gamma K_k) f(\theta) + Y_\tau (1 - F(\theta)) \left[-\frac{q(\theta)}{c} - \left(1 - \frac{q(\theta)}{c} \right) \right] \\
\Leftrightarrow 0 &= \lambda V_k - \gamma K_k + (1 - \lambda) \frac{1 - F(\theta)}{f(\theta)} \\
\Leftrightarrow k(\theta) &= c \left[\theta + \frac{1 - \lambda}{\lambda} \frac{1 - F(\theta)}{f(\theta)} - \frac{\gamma}{\lambda} K_k \right].
\end{aligned}
$$

This concludes the proof.

Finally, the thresholds are ordered as $\underline{\theta} < \widehat{\theta} < \theta^* < \overline{\theta}$, where θ^* is the maximizer of $k^*(\theta)$ or $\theta^* = \left(\lambda - \frac{1}{2} \right) \frac{\overline{\theta}}{\gamma}$. Note that $\lambda < \overline{\lambda}$ ensures that $\theta^* < \overline{\theta}$ and $\widehat{\theta} < \theta^*$. Moreover, $\underline{\theta} < \widehat{\theta}$ holds for $\lambda > \underline{\lambda} = \left(\sqrt{22} + 2 \right) \frac{1}{9}$. For $\gamma < \frac{1}{2}$, $\widehat{\lambda} < \underline{\lambda} < \overline{\lambda}$ so requiring $\lambda \in (\underline{\lambda}, \overline{\lambda})$ yields the ordering.

Proof of Lemma 2 From the expression of $\widehat{k}^R(\theta)$ in Proposition 3, first compute $\frac{\partial}{\partial \theta} \widehat{k}^R(\theta) = \frac{c}{\lambda} \left[(1 - \lambda) + 2\gamma \left(\frac{\theta}{\overline{\theta}} \right)^2 \right] > 0$ for $\theta \in [\underline{\theta}, \widehat{\theta}]$ and $\widehat{\theta}(\overline{\theta}) \in (\underline{\theta}, \overline{\theta})$. Second, compute $\overline{k}(\overline{\theta})' = c \left[\frac{3(2\lambda - 1)^2 - 4\gamma(2\lambda - 3 - \gamma)}{16\lambda\gamma} \right]$, which is positive under the Assumption (p.16).

Proof of Lemma 3 First, from the expression of $\widehat{\theta}$ in Proposition 3, compute $\widehat{\theta}'(\overline{\theta}) = \frac{3(2\lambda - 1) - 2\gamma}{4\gamma}$, which is in $(0, 1)$ for $\lambda \in (\underline{\lambda}, \overline{\lambda})$. Hence, $\frac{\overline{\theta} - \widehat{\theta}(\overline{\theta})}{\overline{\theta}}$ increases in $\overline{\theta}$. Second, compute $\widehat{\theta}'(\gamma) = -\frac{3}{2\gamma^2} (\lambda - \frac{1}{2}) \overline{\theta}$, which is negative for $\lambda > \underline{\lambda}$. Hence, $\frac{\overline{\theta} - \widehat{\theta}(\gamma)}{\overline{\theta}}$ increases in γ.