Dynamic Prudential Regulation

Ajay Subramanian Baozhong Yang

Robinson College of Business
Georgia State University

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Motivation

- 2007–2009 financial crisis—importance of regulation of banks and other financial institutions
- How does regulation impact various stakeholders of banks?
- What forms should regulatory intervention optimally take?
  - Capital requirement
  - Intervention in operations
  - Bailout or Liquidation
- What are the relative impacts of different components of regulation?
- How sensitive is optimal prudential regulation to the economic environment?

Introduction

- Inter-temporal nature of banks' operations and regulatory intervention policies—dynamic model that is analytically tractable and is "calibratable"
  - Qualitative insights on the form and properties of optimal regulatory policies
  - Quantitative guidance on design and impact of prudential regulation
- We develop a dynamic (continuous-time) model to analyze design of prudential regulation and its impact on the real and financial decisions of banks
- Positive and normative objectives
  - How do existing regulatory policies affect banks' investment and financing decisions
  - Design of "optimal" prudential regulation

Overview of Results I

- Analytical characterization of optimal regulatory policy—multi-pronged in nature
- Capital requirement
  - Restriction on bank's initial leverage
- Risk intervention
  - Intervention to control bank risk
- Bailout policy
  - Injection of capital after bank becomes insolvent
  - Bank liquidation

Overview of Results II

- We calibrate the model to U.S. banks in 1991–2008
- Regulation increases bank leverage substantially, while lowering its credit spread, relative to benchmark unregulated bank
- Optimal initial capital requirement is close to **20%**—consistent with higher requirements advocated by recent studies (e.g. Admati, DeMarzo, Hellwig and Pfleiderer (2011))
- Capital injection and risk intervention *independently* have only modest effects on social value
- Optimal combination significantly improves social value by **4.4%** and bank value by **12%**
- Prudential regulation should not be independent of monetary and fiscal policies

Model Overview

- Continuous-time model of a representative bank operating in a regulated environment
- Bank chooses capital structure at date zero that consists of equity and debt
- Additional deadweight costs of equity issuance relative to debt issuance
  - Banks' fundamental role of "intermediation"—transformation of illiquid long-term loans into liquid, "information insensitive" debt securities
  - Banks' comparative advantage in raising capital through debt
- Bank's capital structure trades off excess costs of equity issuance against "financial distress" costs due to debt

Model Overview

- Market participants risk-neutral—discount payoffs at risk-free rate
  - Could alternatively view the model as a "contingent claims" model under the risk-neutral measure
- Bank can dynamically alter the distribution of its earnings
  - Two projects: "low-risk" project and "high-risk" project
  - High risk project has lower drift – asset substitution

Model Overview

- Broad gamut of regulatory intervention policies
  - Initial capital requirement
  - Intervention in risk choices
  - Capital injection (Bailout)
  - Liquidation
- Potential benefits of regulation
  - Bank maximizes shareholder value
  - Regulator maximizes "social value" that internalizes claims of shareholders, debt-holders and tax payers (injection of public funds)
  - Regulator also internalizes effects of systemic risk—externality that bank imposes on economy through its financial distress

Model

- Continuous time horizon: $t \in [0, \infty)$
- A bank can dynamically select project 1 or 2
- The total earnings of the bank C_t

$$\begin{aligned} dC_t &= \mu_1 C_t dt + \sigma_1 C_t dB_t, \text{ if project 1 is chosen,} \\ dC_t &= \mu_2 C_t dt + \sigma_2 C_t dB_t, \text{ if project 2 is chosen.} \end{aligned}$$

- Asset substitution

$$\mu_1 > \mu_2 \text{ and } \sigma_1 < \sigma_2.$$

Capital Structure

- The bank chooses initial debt level
- Cash flow to debt holders: θdt
- Cash flow to equity holders:

$$\begin{aligned} &= (C_t - \theta)dt - \lambda_1(C_t - \theta)dt \quad \text{if } C_t \geq \theta \\ &= (C_t - \theta)dt - \lambda_2|C_t - \theta|dt \quad \text{if } C_t < \theta, \end{aligned}$$

- λ_1: excess cost of equity issuance
- λ_2: costs due to financial distress
- Bank services debt entirely as long as it is solvent—becomes insolvent at stopping time τ_B.
- For $t > \tau_B$, regulator takes control and injects capital until liquidation time $\tau_L \geq \tau_B$.

Bank's and Regulator's Strategies

- Bank's strategy is an $\mathscr{F}_t-$adapted process

$$\Pi = (P, \tau_B)$$

  - $P_t \in (1,2)$: the bank's project choice at t
  - τ_B: insolvency time at which the bank stops issuing equity to service debt

- Regulator's intervention strategy is an $\mathscr{F}_t-$adapted process

$$\Pi^{reg} = (P^{reg}, \tau_L)$$

  - $P_t^{reg} \in (1,2)$: the regulator's project choice at t
  - τ_L : liquidation time at which the regulator stops injection and liquidates the bank

Equity and Debt Value

- Debt value

$$D_t(\theta, \Pi, \Pi^{reg}) = E_t \int_t^{\tau_L} e^{-r(u-t)} \theta \, du + E_t[e^{-r(\tau_L - t)} D_{\tau_L}]$$

- Equity value: $(C_t = C_t(\Pi, \Pi^{reg}))$

$$S_t(\theta, \Pi, \Pi^{reg}) = E_t \int_t^{\tau_B} e^{-r(u-t)} \left[\begin{array}{c} 1_{C_u \geq \theta}(1-\lambda_1)(C_u - \theta) + \\ 1_{C_u < \theta}(1+\lambda_2)(C_u - \theta) \end{array} \right] du$$

- In the above, D_{τ_L} is the debt value at liquidation

$$D_{\tau_L} = \frac{(1-\alpha)(1-\lambda_1)C_{\tau_L}}{r - \mu_1}$$

- Liquidation costs—debtholders receive proportion $1-\alpha$ of unlevered bank value at liquidation threshold

Bank and Social Values

- Bank value

$$F_t(\theta,\Pi,\Pi^{reg}) = D_t(\theta,\Pi,\Pi^{reg}) + S_t(\theta,\Pi,\Pi^{reg})$$

$$= E_t \int_t^{\tau_B} e^{-r(u-t)} \left\{ \left[\begin{array}{c} 1_{C_u \geq \theta}\left((1-\lambda_1)C_u + \lambda_1\theta\right) + \\ 1_{C_u < \theta}\left((1+\lambda_2)C_u - \lambda_2\theta\right) \end{array} \right] \right\} du$$

$$+ E_t \int_{\tau_B}^{\tau_L} e^{-r(u-t)}\theta\, du + E_t[e^{-r(\tau_L - t)} D_{\tau_L}]$$

- Social value

$$F_t^{social}(\theta,\Pi,\Pi^{reg})$$

$$= E_t \int_t^{\tau_L} e^{-r(u-t)} \left\{ \left[\begin{array}{c} 1_{C_u \geq \theta}\left((1-\lambda_1^{social})C_u + \lambda_1^{social}\theta\right) + \\ 1_{C_u < \theta}\left((1+\lambda_2^{social})C_u - \lambda_2^{social}\theta\right) \end{array} \right] \right\} du$$

$$+ E_t[e^{-r(\tau_L - t)} D_{\tau_L}^{social}]$$

Bank and Social Costs

- Wedges between costs faced by bank, $\lambda_1, \lambda_2, \alpha$, and those viewed by regulator, $\lambda_1^{social}, \lambda_2^{social}, \alpha^{social}$.
- Debt tax shields are simply transfers that do not appear in regulator's objective function so that $\lambda_1^{social} \leq \lambda_1$.
  - Regulator does acknowledge banks' important role as financial intermediaries
- Financial distress costs faced by bank do not necessarily internalize systemic costs imposed on the economy so that $\lambda_2^{social} \geq \lambda_2$, $\alpha^{social} \geq \alpha$.
- Wedges between "bank" and "social" costs incorporate effects of systemic risk

Objectives of the Bank and the Regulator I

- **Case** 1: Unregulated bank
  - Given debt level θ, the bank's optimal strategy maximizes *equity value*
$$\Pi^*(\theta) = \arg\max_{\Pi} S_0(\theta, \Pi)$$
  - The bank's optimal capital structure maximizes initial *bank value*
$$\theta^* = \arg\max_{\theta} F_0(\theta, \Pi^*(\theta))$$

Objectives of the Bank and the Regulator II

- **Case** 2: Full regulation case:
  - Given debt level θ and regulator's strategy Π^{reg}, the bank's optimal strategy maximizes *equity value*

$$\Pi^*(\theta, \Pi^{reg}) = \arg\max_{\Pi} S_0(\theta, \Pi, \Pi^{reg})$$

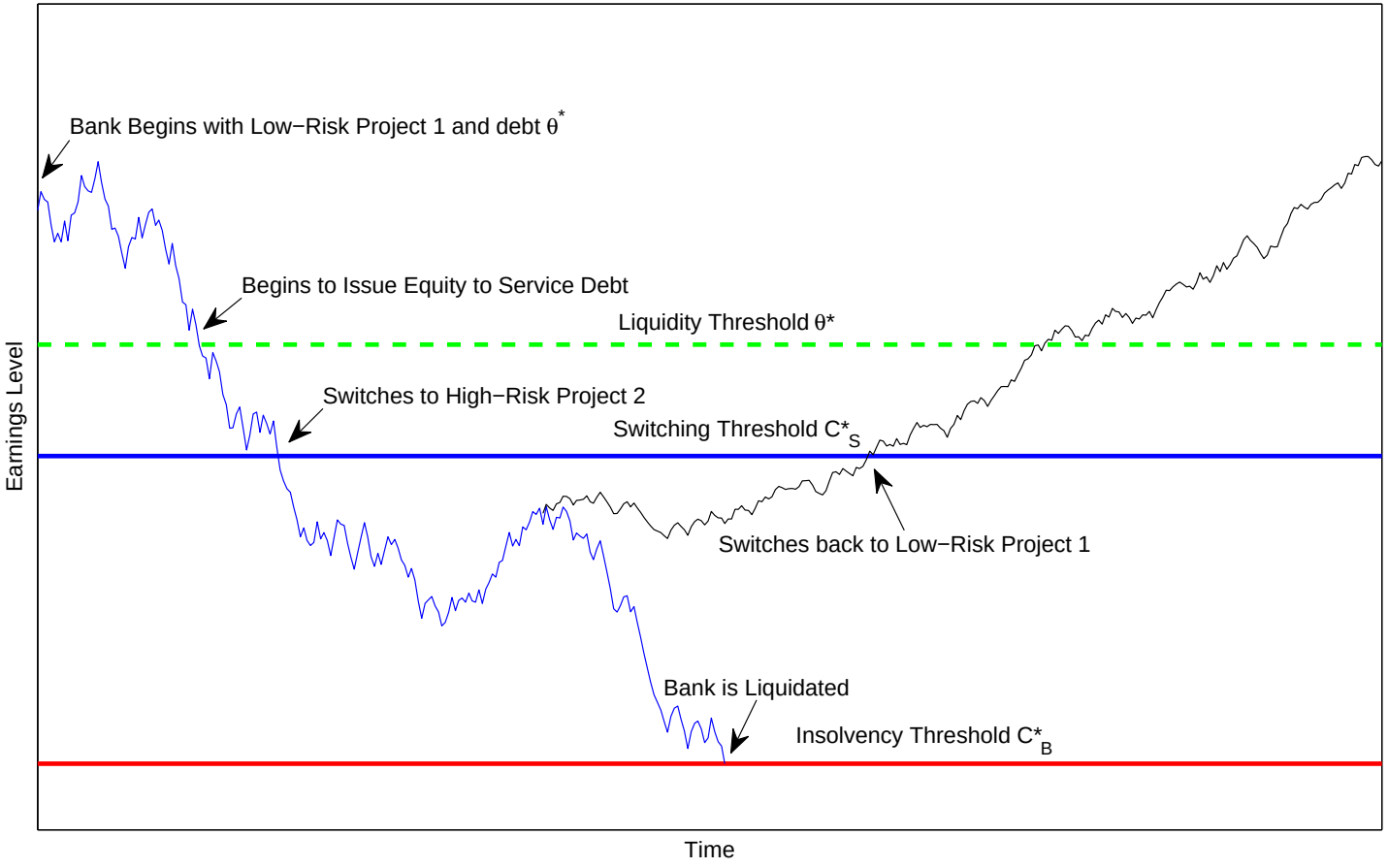
  - The regulator's optimal initial capital requirement and optimal strategy maximizes *social value*

$$(\theta^{*reg}, \Pi^{*reg}) = \arg\max_{(\theta, \Pi^{reg})} F_0^{social}(\theta, \Pi^*(\theta, \Pi^{reg}), \Pi^{reg})$$

Main Results I: Unregulated Bank

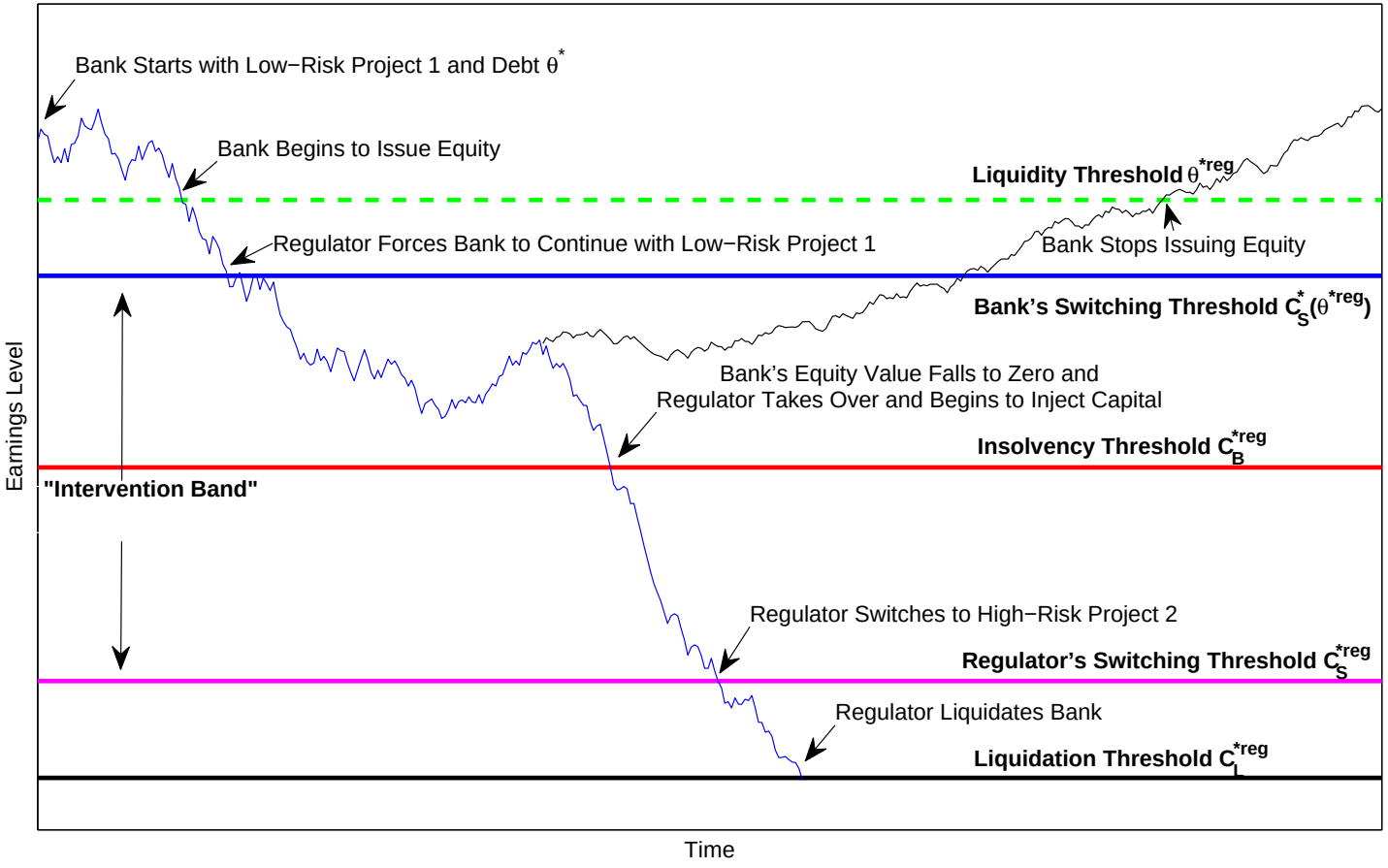
- Closed-form characterization of the unregulated bank's optimal strategy
  - Optimal initial capital structure
  - Optimal dynamic risk policy: asset substitution below a *switching threshold*
  - Raise equity when the bank is illiquid but solvent
  - Endogenous bankruptcy

Illustration: Unregulated Bank's Optimal Policy



- Closed-form characterization of the optimal regulatory policy
  - Imposition of initial capital requirement: prevents excessive leverage
  - Optimal risk intervention policy: reduces asset substitution
    - "Band" strategy: the regulator intervenes in bank's risk choices when earnings lie between two triggers
    - The regulator also substitutes assets when bank's earnings are sufficiently low
  - Capital injection when the bank is insolvent: implicit insurance to debt holders
  - Liquidation at an optimal threshold

Illustration: Optimal Regulatory Policy



Calibration of Model Parameters I

- Calibrate the model to U.S. banks (Compustat) over the period 1991-2008
- Calibrate the partial regulation model where the bank chooses capital structure and projects, but regulator injects capital and liquidates the bank
  - In reality, U.S. banks not subject to Basel regulations over most of the period
  - Financial crisis—banks not well regulated, but received bailouts using public funds

Calibration of Model Parameters II

- Risk-free rate $r = 3.5\%$: average short-term treasury rate over 1991-2008
- Liquidation cost $\alpha = 0.2$: Andrade and Kaplan (1998) and Davydenko, Strebulaev, and Zhao (2011)
- Asset volatilities $\sigma_1 = 0.126, \sigma_2 = 0.148$: median and 75th percentile of bank asset risk

Calibration of Model Parameters III

- Calibrate drifts μ_1, μ_2 and excess equity costs λ_1, λ_2 to match bank leverage (87%) and credit spread (106 bp) with the following constraints

$$V_0 = \frac{(1-\lambda_1)C_0}{r-\mu_1} + \frac{\lambda_1 \theta}{r}$$

$$\frac{r-\mu_1}{\sigma_1} = \frac{r-\mu_2}{\sigma_2}$$

$\Rightarrow \mu_1 = 0.0\%, \mu_2 = -0.6\%, \lambda_1 = 0.305,\ \lambda_2 = 0.539.$

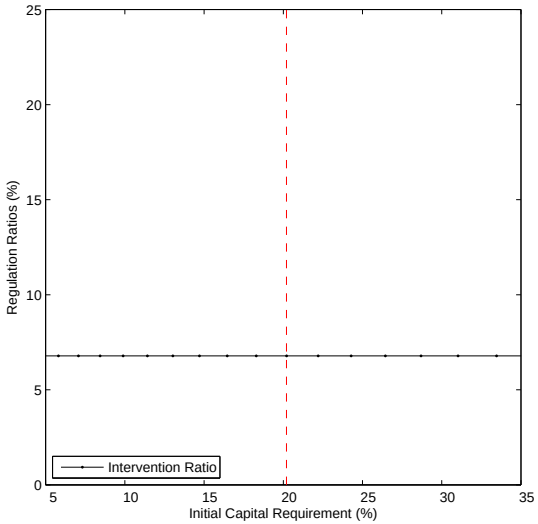
Impact of Optimal Regulation

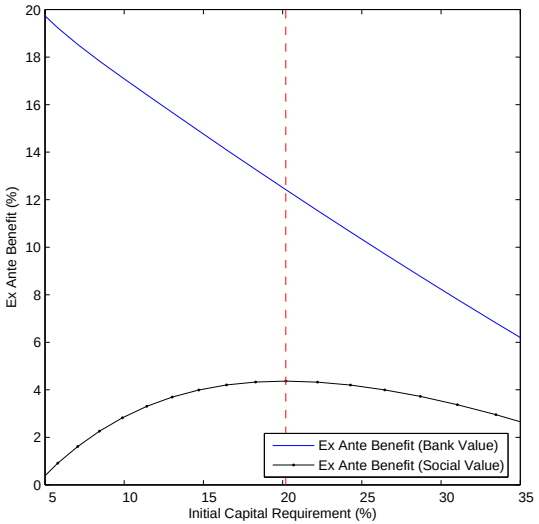
	Unregulated Bank	Full Regulation
Debt Level and Thresholds		
Initial Coupon Level	0.635	0.822
Switching Boundary (Bank)	0.581	0.753
Switching Boundary (Regulator)		0.335
Insolvency Boundary	0.432	0.579
Liquidation Boundary		0.297
Leverage and Regulatory Ratios		
Initial Leverage	64.9%	79.8%
Initial Capital Requirement		**20.2%**
Switching/Intervention Leverage	90.2%	93.2%
Intervention Ratio		**6.8%**
Switching Leverage (Regulator)		145.7%
Spread (bp)	68.6	42.2
Ex Ante Values		
Bank Value	23.346	26.251
Social Value	23.346	24.365
Ex Ante Benefit (Bank Value, %)		12.4%
Ex Ante Benefit (Social Value, %)		**4.4%**
Ex Post Values at Insolvency		
Ex Post Benefit (Bank Value, %)		86.9%
Ex Post Benefit (Social Value, %)		36.3%

Impact of Individual Regulatory Policies

	Unregulated Bank	Capital Injection Only	Investment Intervention Only	Full Regulation with No Initial Capital Requirement	Full Regulation
Leverage and Regulatory Ratios					
Initial Leverage	64.9%	87%	66.4%	100%	79.8%
Initial Capital Requirement					20.2%
Intervention Ratio		8.0%	9.8%	6.8%	6.8%
Ex Ante Values					
Firm Value	23.346	25.226	23.442	31.133	26.251
Social Value	23.346	23.177	23.442	19.496	24.365
Ex Ante Benefit (Bank Value, %)		8.1%	0.4%	33.4%	12.4%
Ex Ante Benefit (Social Value, %)		**-0.7%**	**0.4%**	**-16.5%**	**4.4%**

Impact of Changes in Initial Capital Requirement

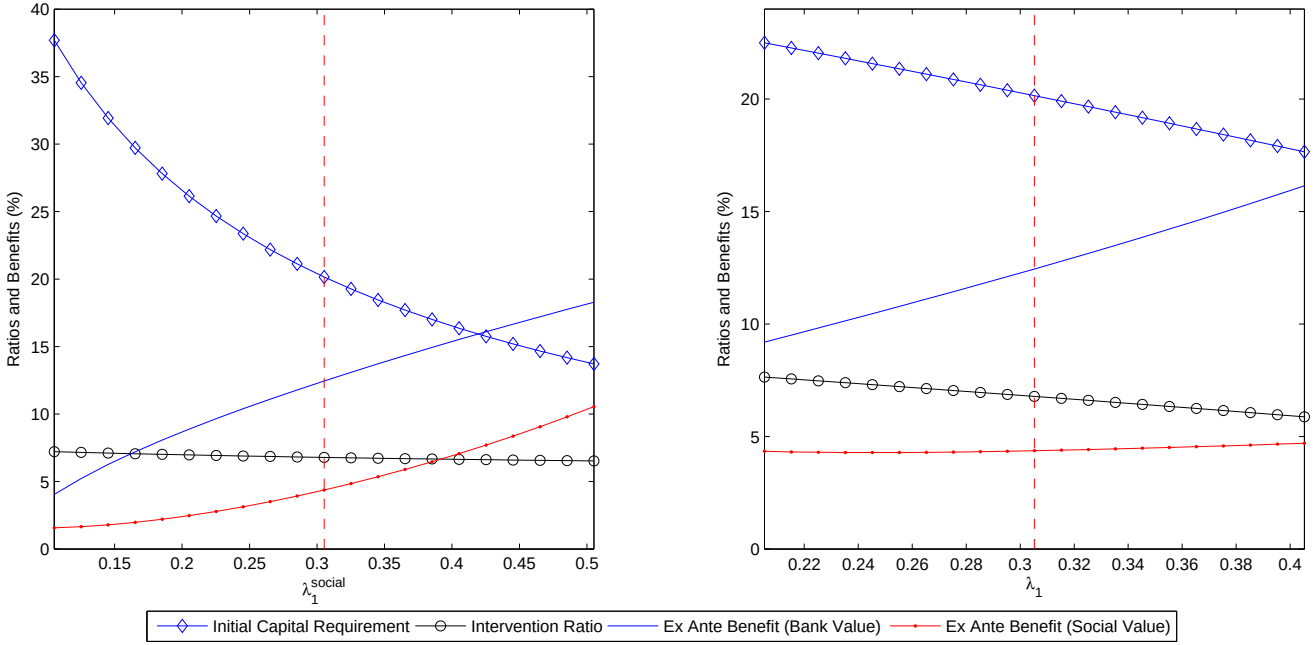




What if the regulator does not impose capital requirement optimally?

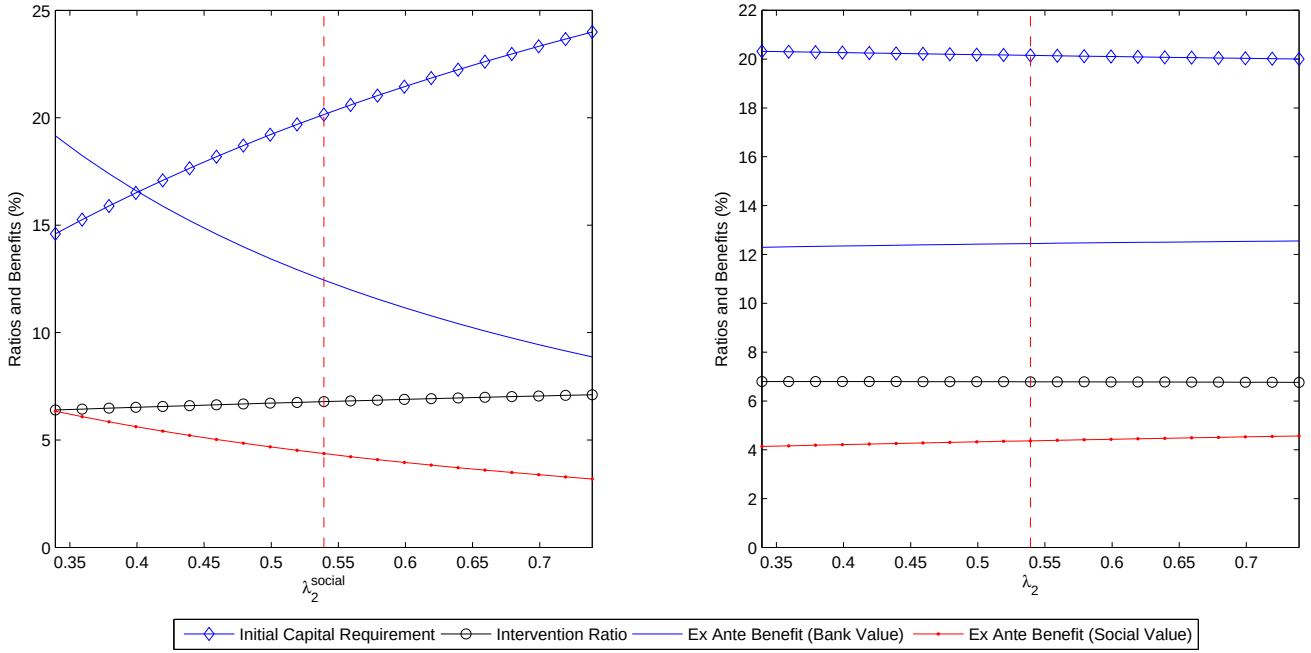
- Assume other policies (intervention, capital injection) still optimal
- Constant intervention ratio (switching leverage independent of initial capital structure)
- Social benefit significantly reduced with lower capital requirement (despite increase in bank value)
  - Reduced by **2.4 percentage points** when the Basel II capital requirement of **8%** is imposed

Social and Bank Costs of Equity λ_1^{social} and λ_1



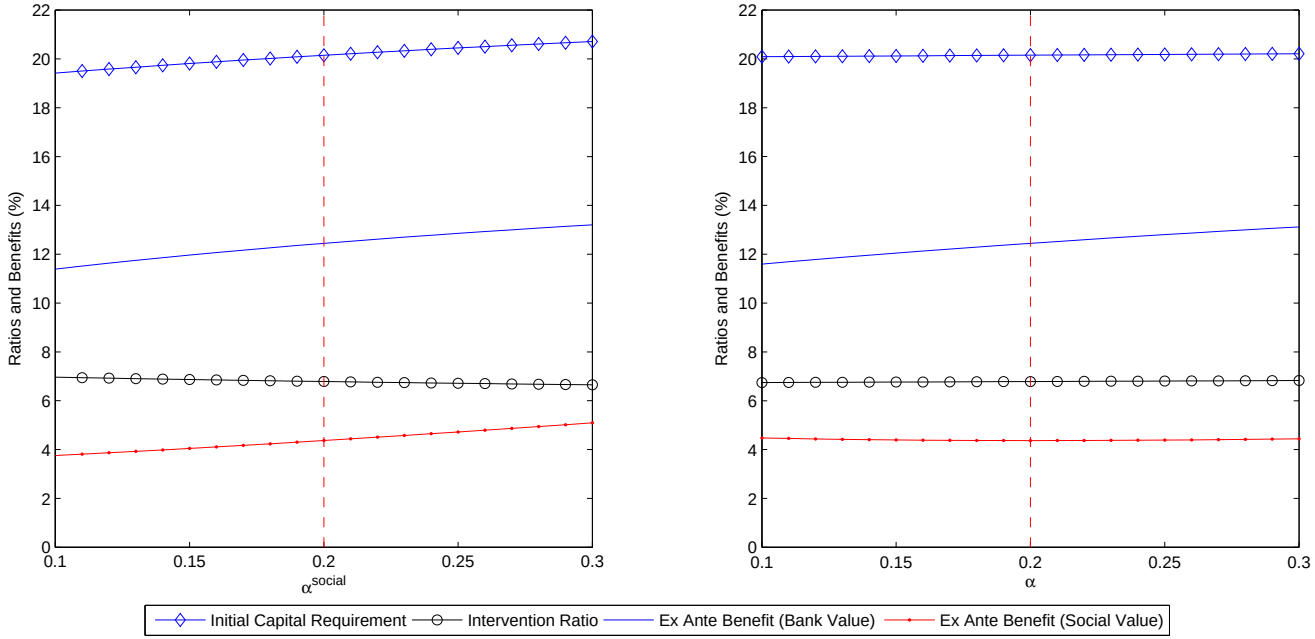
- Optimal capital requirement
  - Decreases sharply with excess social cost of equity λ_1^{social}: higher social benefits of debt $\Rightarrow$ higher optimal debt level
  - Decreases with bank cost of equity λ_1: lower equity value $\Rightarrow$ higher leverage
  - **Higher tax rate** $\Rightarrow$ higher λ_1 and **lower capital requirement**
    - Regulation and fiscal policy should be determined together
- Social benefit increases with social cost of equity but not with bank's private cost of equity

Social and Bank Distress Costs λ_2^{social} and λ_2



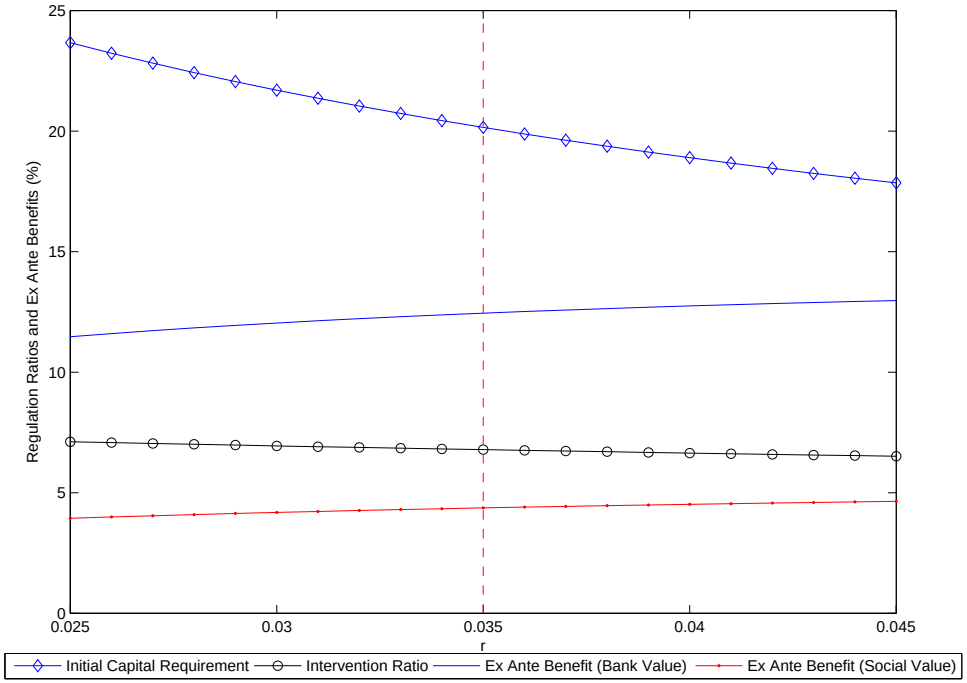
- Optimal capital requirement
  - Increases with social distress cost λ_2^{social}
  - Independent of bank's private distress cost λ_2
- Social benefit decreases with social distress cost, due to lower leverage and higher injection costs
- Expected costs of capital injection depends *negatively* on cost of injection

Social and Bank Liquidation Costs α^{social} and α



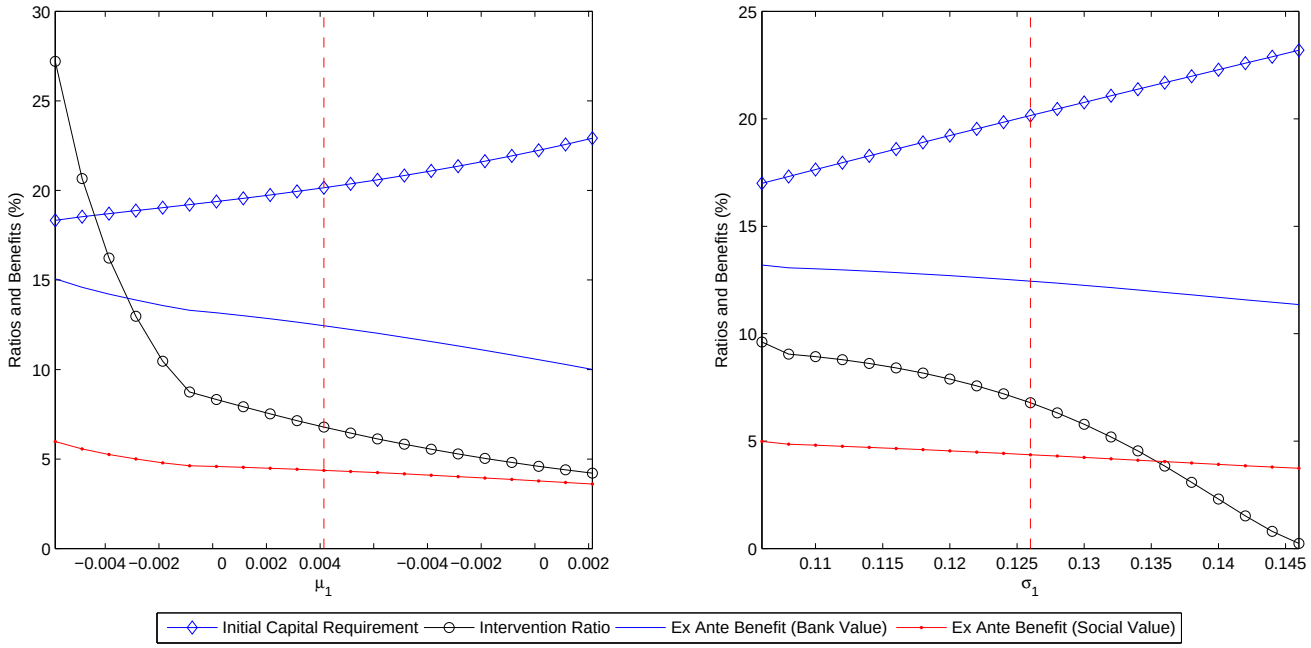
- Optimal capital requirement increases slightly with social liquidation cost
  - Capital injection delays liquidation and offsets the negative impact of liquidation cost on debt value and leverage
- Social benefit increases with social liquidation cost: delayed liquidation through capital injection is socially beneficial

Risk-Free Rate r and Optimal Regulation



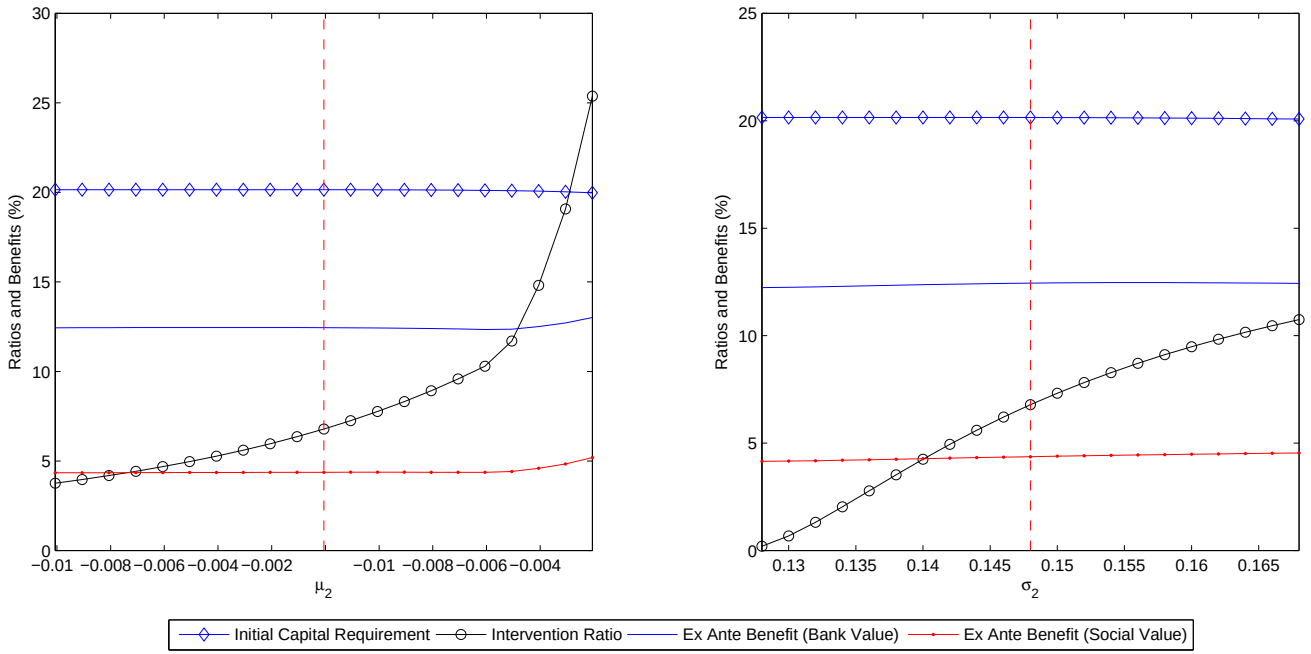
- Optimal capital requirement decreases with risk-free rate: lower expected default costs $\Rightarrow$ higher optimal leverage
  - capital requirements affected by monetary policy
- Optimal Intervention ratio insensitive to risk-free rate
- Social benefit of regulation increases slightly with risk-free rate
  - Leverage effect: benefits of regulation higher when initial leverage is higher

Impact of Changes in Low-Risk Project Drift and Volatility



- Optimal capital requirement increases with low-risk project drift μ_1 and volatility σ_1: high-growth high-risk banks $\Rightarrow$ lower optimal dynamic leverage
- Optimal Intervention ratio decreases with low-risk project drift and volatility: low-risk project is more attractive with higher drift and vol.
- Social benefit of regulation decreases slightly: leverage effect.

Impact of Changes in High-Risk Project Drift and Volatility



- Optimal capital requirement insensitive to high-risk project drift μ_2 and volatility σ_2: high-risk project seldom adopted under regulation
- Optimal Intervention ratio increases with high-risk project drift and volatility

Conclusion I

- A continuous-time model
  - The bank dynamically engage in asset substitution
  - Capital structure:
    - Excess costs of equity relative to debt
    - Costly liquidation
  - The regulator can impose initial capital requirement, intervene in the bank's risk choices, inject capital, and force liquidation
- Optimal regulatory policy
  - Closed-form characterization
  - Single switching thresholds in the bank and regulator's problem
  - Risk intervention when earnings are inside a "band"
  - Regulator also engages in asset substitution when earnings are low

Conclusion II

- Quantitative implications from calibration
  - Optimal regulation significantly improves social value (4.4%) and bank value (12%)
  - Individual components has limited or negative impact on social value
  - Optimal initial capital requirement (20%) much higher than the Basel II requirement
  - Optimal capital requirement and risk intervention depends on economic environment

Literature Review: Bank Capital and Regulation

- **Bank's Monitoring Role and Moral Hazard**: Diamond (1984), Giammmarino, Lewis, and Sappington (1993), Holmström and Tirole (1997), Allen, Carletti, and Marquez (2011), Mehran and Thakor (2011), Acharya, Mehran, and Thakor (2011)
- **Bank's Liquidity Provision Role**: Diamond and Dybvig (1983), Gorton and Winton (1995), Diamond and Rajan (2000)
- **Bank Capital, Deposit Insurance, and Asset Substitution**: Merton (1977), Kareken and Wallace (1978), and Sharpe (1978), Koehn and Santomero (1980), Kim and Santomero (1988), Rochet (1992), Marshall and Prescott (2001, 2006)
- **Asset Substitution for Non-Financial Firms**: Jensen and Meckling (1976), Leland (1998)
- **Dynamic Models**: Zhu (2008), Van den Heuvel (2009), De Nicolò, Gamba, and Lucchetta (2011)