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A Regulatory Arbitrage Game: Off-Balance-Sheet Leverage and Financial Fragility

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Motivation 1-3

- The pre-financial crisis period was characterized by high leverage of financial institutions
- Banks leveraged their position by transfering a large part of their assets off their balance sheet
- By and large, all financial institutions were engaged in off-balance-sheet activities, including
  - securitizations (CDO's)
  - transfers of accounts receivable (high-default loans and/or NPL's)
  - swaps (interest, FX, credit) and other OTC derivatives
- Information about these activities are hard to be traced (are included in accompanying notes)

Questions

How much destabilizing are the off-balance-sheet activities?
Can we measure the effect?
How banks decide their effective leverage in this framework?

Motivation 2-3

A major lesson learned from the financial crisis of 2007–09 is that limited information about OTC derivatives was available to regulators and policymakers. Recognising that the lack of comprehensive data on OTC derivatives severely constrained the ability of regulators to fashion appropriate policy responses during that period of market stress, as regulators did not have a clear view of the positions of market participants, the G20 in 2009 mandated that all OTC derivatives contracts be reported to TRs (trade repositories).

CPSS-IOSCO – Report on data reporting and aggregation requirements – January 2012

Motivation 3-3

What is the regulatory arbitrage?

A game between banks and financial regulatory authorities (FRA). The FRA pursue to keep sound the financial system at the cost of banks' leverage. The banks attempt to evade the regulatory cost and increase their leverage.

- Think financial stability as a common-pool resource. Banks pursue to evade the ”regulatory tax” at the expense of financial stability
- This is a typical ”tragedy of commons problem”
- Once the ”common-pool” of financial stability will be depleted, all banks will incur the cost of financial distress

How far banks can be engaged in regulatory arbitrage and enjoy the benefits of regulatory tax evasion at the expense of financial stability?

The toolkit - Related Literature

- The main contribution is the introduction of an inefficiency metric (PoA) originated to Koutsoupias and Papadimitriou (2009)) and further extended for mixed Nash and correlated by Roughgarden (2009), incomplete information, Roughgarden (2012). In economics literature the same metric can be found in Moulin (2007) and Rouben (2006))
- The game admits a best response potential function (Voorneveld,2000) and belongs to the broader class of potential games (Monderer and Shapley 1996)
- The case for malicious bankers has been adopted by Moscibroda, Schmid and Wattenhofer (2006)

The balance sheet

- The game is played by n banks under the policy suggested by a Financial Regulatory Authority (FRA)
- The balance sheet of bank i

Balance Sheet			
Assets		**Liabilities**	
Cash	$\theta \cdot D_i$	Deposits	D_i
Asset	A_i	Ordinary Capital	K_i
Total Assets	$\theta \cdot D_i + A_i$	Total Liabilities	$D_i + K_i$

- The return on deposits and cash balances is normalized to zero
- There is a single risk free asset with positive return $r^m > 0$
- Banks hold the minimum cash balances required by the FRA (reserve requirements θ)
- Overall, the policy mix is a pair (ψ, θ), the capital adequacy ratio and the reserve ratio

The regulatory tax = Foregone profits

- Elastic supply of deposits
- Depositors cannot invest directly to the asset
- Banks are privileged to transform deposits to asset
- The introduction of “regulatory tax” amounts to the opportunity cost of holding excess capital and cash reserves.

$$RT_i = \psi \cdot A_i \cdot r^m + \theta \cdot D_i \cdot r^m = r^m(\psi \cdot A_i + \theta \cdot D_i).$$

- The “regulatory tax” attributes the foregone profits incurred by the bank

The expected cost function - Full immunization

The expected cost

$$C_i = \alpha_i \overbrace{\left[r^m(\psi \cdot A_i + \theta \cdot D_i)\right]}^{\text{Foregone profits}} + (1 - \alpha_i) \overbrace{\frac{\sum_{j=1}^{\#S}(1 - \alpha_j)}{n}}^{\text{Prob. of fin. distress}} \underbrace{\omega \cdot A_i}_{\text{Losses}}$$

- The bank decides to bear a part of the "regulatory tax" (α_i) and transfer a part of its assets off-the-balance sheet ($1 - \alpha_i$)
- the less the α's the higher the probability of financial distress

$$\frac{\sum_{j=1}^{\#S}(1 - \alpha_j)}{n}$$

- In case of financial distress, banks incur a horizontal haircut of their assets $\omega \in (0, 1)$ of their assets A_i.
- Furthermore, we assume that the asset haircut sufficiently exceeds the regulatory tax.

An alternative specification

- A drawback of this specification is that it assumes that once a bank fully complies with the regulatory policy, it becomes immune to financial distress
- An alternative specification that banks cannot fully immunized is the following

The expected cost with contagion effect

$$C_i = \alpha_i[r^m(\psi \cdot A_i + \theta \cdot D_i)] + \frac{(1-\alpha_i)}{n}\omega \cdot A_i + \frac{\sum_{j \neq i}(1-\alpha_j)}{n}\omega \cdot A_i.$$

The Regulatory Arbitrage Game (RAG)

The game

$$\Gamma = \{I, \{[0,1]\}_{i \in I}, \{C_i\}_{i \in I}, (\psi, \theta)\}.$$

The FRA (pseudoplayer)

The FRA would minimize the objective

$$C_{n+1} = |PFA - 1|$$

by appropriately choosing the policy parameters (ψ, θ)

The equilibrium

The strategic equilibrium is a strategy profile $((\psi, \theta), \alpha^*)$ such that for all *i* banks and the FRA

$$C_i((\psi, \theta), \alpha^*)) \leq C_i((\psi, \theta), (\alpha_i, \alpha^*_{-i})) \text{ for all } \alpha_i$$

The best response potential

The Regulatory Arbitrage Game admits a best response potential $P : [0,1]^n \mapsto R$ i.e.

$$\arg\min_{\alpha_i} C_i(\alpha) = \arg\min_{\alpha_i} P(\alpha)$$

The best response potential

$$P(\alpha) = \sum_i (1-\alpha_i)^2 \frac{\omega A_i}{n}.$$

Proposition

The strategic equilibrium of the regulatory arbitrage game always exists.

Why a potential function?

- We could use a fixed-point argument (Tarski fixed point theorem) to prove existence.
- For practical reasons. Potential functions are computationally tractable. We can calculate the individual level of tax evasion at equilibrium.
- On top of that, we can calculate the strategic inefficiency, rather than merely order equilibria as suggested by Tarski fixed-point theorem.

The RAG is submodular

- submodular game = strategic substitutes
- When opponents evade less (α_j increases for some j's), the increase of my tax evasion (α_i decreases) is cost saving

Decreasing differences

We say that the cost function exhibits (linear) decreasing differences if for $\alpha_i \geq \alpha_i'$ and $\alpha_j \geq \alpha_j'$ it is

$$C_i(\alpha_i, \alpha_j) - C_i(\alpha_i, \alpha_j') < (=) C_i(\alpha_i', \alpha_j) - C_i(\alpha_i', \alpha_j'), \quad \forall i \in I \setminus \{n+1\}. \tag{1}$$

Lemma

The cost function of banks in the regulatory arbitrage game exhibits decreasing differences i.e., for $\alpha_i \geq \alpha_i'$ and $\alpha_j \geq \alpha_j'$ it is

$$C_i(\alpha_i, \alpha_j) - C_i(\alpha_i, \alpha_j') \leq C_i(\alpha_i', \alpha_j) - C_i(\alpha_i', \alpha_j'), \quad \forall \in I \setminus \{n+1\}.$$

For the cost function with contagion effect we have the linear case.

Measuring inefficiency

- The socially optimum is zero evasion i.e. $\alpha = \mathbf{1}$. Denote the overall regulatory cost at the social optimum by $\bar{\mathbf{C}}$ (SOC)
- The overall cost at the strategic equilibrium is $\mathbf{C}^* = \sum_i \mathbf{C}_i((\psi, \theta), \alpha^*)$

Price of Financial Anarchy

PFA is defined as the maximum deviation from social optimum cost for the worst-case equilibrium in the set of equilibria. It is the ratio

$$PFA = \max_{\alpha^* \in NE} \frac{\mathbf{C}^*}{\bar{\mathbf{C}}}. \quad (2)$$

The boundedness of PFA 1-3

- Positive pivotal cost PC_i^+. All banks but i comply fully with the regulatory policy. Bank i opts for equilibrium strategy α_i^*.
- Negative pivotal cost PC_i^-. When bank i unilaterally complies fully to regulatory policy.

$$PC_i^+ \leq C_i((\psi, \theta), \alpha = \mathbf{1}) \leq PC_i^- .$$

Assumption

$$PC_i^- - C_i((\psi, \theta), \alpha = \mathbf{1}) \geq C_i((\psi, \theta), \alpha = \mathbf{1}) - PC_i^+ .$$

- The cost of compliant exceeds the benefit of the deviant. It pays to be a crook!

The boundedness of PFA 2-3

Average pivotal cost

$$APC_i = (PC_i^+ + PC_i^-)/2,$$

attributes the net effect of unilateral deviations.

Total average pivotal cost

$$TAPC = \sum_i APC_i,$$

submodularity is inherited by the cost function

The boundedness of PFA 3-3

Proposition

The PFA is bounded from above by

$$\max_{\alpha^*}\left\{\frac{2TAPC - SOC}{SOC}\right\}$$

- Under the previous assumption, the upper bound is always greater to 1
- The result suggests that the higher the upper bound the more vulnerable the financial system will be
- The banks could become more opportunistic

Corollary

The strategic equilibrium is always inefficient.

The game with malicious bankers

- Malicious or Byzantine bankers = willfully destabilizing bankers

Byzantine Generals Problem

This situation can be expressed abstractly in terms of a group of generals of the Byzantine army camped with their troops around an enemy city. Communicating only by messenger, the generals must agree upon a common battle plan. However, one or more of them may be traitors who will try to confuse the others.

- One or more banks short the market - assume that their trades are not traceable (i.e. dark pool trading)

The game with malicious (Byzantine) bankers

- A subset of bankers pursue financial distress (i.e. their long in credit derivatives or short in assets)
- $I = I^p \cup I^m \cup \{FRA\}$
- Malicious bankers maximize the probability of financial distress and for all $i \in I^m$ we have $\alpha_i = 0$

The Byzantine Regulatory Arbitrage Game

The Byzantine regulatory arbitrage game is defined by the cost minimization game

$$\Gamma = \{I, \{[0,1]\}_{i \in I}, \{C_i\}_{i \in I^p}, \{C_i\}_{i \in I^m}, (\psi, \theta)\}.$$

- The Social Cost (SOC) excludes malicious banks
- $\bar{\mathbf{C}} = \sum_{i \in I^p} C_i((\psi, \theta, \alpha = \mathbf{1} | I^m)$ -social cost
- $\mathbf{C}^* = \sum_{i \in I^p} C_i((\psi, \theta), \alpha^* | I^m)$ - overall cost of profit maximizing bankers at equilibrium

PBFA

$$PBFA(I^p; I^m) = \max_{\alpha^* \in NE} \frac{\mathbf{C}^*}{\bar{\mathbf{C}}}.$$

The Price of Malice

The Price of Malice measures the inefficiency in the system caused by the presence of Byzantine bankers and is given by the ratio

$$PoM(I^m) = \frac{PBFA(I^p; I^m)}{PFA(I^p)}.$$

Bounds to inefficiency 1-2

Proposition

PBFA is bounded from above by the ratio

$$\max_{\alpha^*}\left\{\frac{2TAPC - SOC}{SOC} + m\Gamma\right\}.$$

with $\Gamma = \sum_{lp}(1-\alpha_j)\cdot\frac{\omega A_i}{n} > 0$

- The upper bound is higher by the presence of malicious bankers
- The second part captures the effect of malicious behavior

Bounds to inefficiency 2-2

Corrolary

PoM in the Byzantine regulatory arbitrage game is

$$PoM(I^m) = \frac{m\Gamma \cdot SOC}{2TAPC - SOC}$$

- # malicious players $\nearrow$ then PoM $\nearrow$
- SOC $\nearrow$ then PoM $\nearrow$

Conclusions

- We provide an abstract, still powerful, framework to address the strategic considerations of banks as financial actors
- Banks have the opportunity to increase incognito their leverage and make extra profits
- The price of Financial Anarchy is introduced to measure strategic inefficiency
- Ideally for the FRA, the PFA should be 1. We illustrate that the PFA metric can be bounded away to 1. Keeping PFA away of one, the financial system is more unstable, and hence more fragile to shocks
- Byzantine bankers always seek to circumvent regulations to profit from financial turmoil, and that opportunity emerges in upturns and downturns. We take into consideration these perverse incentives

Thank you for your attention!