# Optimal Banking Contracts and Financial Fragility

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# Financial fragility

- Banks and other financial intermediaries appear to be *fragile*
  - that is, susceptible to events in which depositors/creditors suddenly withdraw funding (a *bank run*)

- General question: Why does this happen?
  - *i.e.*, what are the fundamental cause(s) of financial fragility?
  - critical for understanding what can/should be done about it

- Many possible answers:
  - poor/distorted incentives due to limited liability or anticipated government support (bailouts), externalities (fire sales), or bounded rationality in contracts or in forecasts

- Each of these problems might be addressed through regulation

# Diamond & Dybvig (JPE, 1983)

- However: the classic paper of Diamond and Dybvig suggests banking is *inherently fragile*

- They study a model with rational agents and no incentive distortions
  - banking contract is chosen to maximize welfare
  - no role for regulation/macroprudential policy

- Efficient arrangement involves maturity transformation
  - value of bank's short-term liabilities $>$ short-run value of assets

- This arrangement leaves the bank susceptible to a self-fulfilling run
  - if other depositors rush to withdraw ...

$\Rightarrow$ Even with no distortions or other "problems", banking is fragile

- Diamond-Dybvig analysis suggests a stark policy choice:
  - financial stability requires either broad government guarantees (deposit insurance),
  - a “narrow” banking system with no maturity transformation (but this is costly; Wallace, 1996),
  - or living with recurrent crises

- But ... the banking arrangement studied by Diamond & Dybvig was not optimal within their model
  - with no aggregate uncertainty: easy to prevent runs (using suspension of convertibility)
  - with aggregate uncertainty: did not solve for the efficient allocation or banking contract

Q: Does fragility arise under **optimal** banking contracts?

## Outline

- Set up a basic environment
- Discuss the existing literature
  - focus on Green and Lin (2003); Peck and Shell (2003)
- Describe what we do
  - a new specification of the environment
- Results:
  - optimal banking contract has some nice features
  - optimal arrangements **are** sometimes fragile
- Conclude

# A basic environment

- Two periods ($t = 0, 1$) and a finite number $I$ of depositors

- Bank has $I$ units of good at $t = 0$

- Return on investment is $R > 1$ at $t = 1$

- Preferences:

$$u\left(c_i^0 + \omega_i c_i^1\right) = \frac{1}{1-\gamma}\left(c_i^0 + \omega_i c_i^1\right)^{1-\gamma} \qquad \gamma > 1$$

$$\text{where } \omega_i = \left\{ \begin{array}{c} 0 \\ 1 \end{array} \right\} \text{ if depositor is } \left\{ \begin{array}{l} \text{impatient} \\ \text{patient} \end{array} \right\}$$

- A depositor's type is private information
  - prob($\omega_i = 0$) $= \pi$; independent across depositors

- Depositors can visit bank at $t = 0$ or $t = 1$, receive goods (withdraw)

  – arrive one at a time at $t = 0$, in randomly-determined order

  – must consume immediately (Wallace, 1988)

- Sequential service constraint:

  – each payment can depend only on information available to the bank when it is made

  $\Rightarrow$ set of feasible allocations depends on what bank observes

- Features that vary across papers:

  – what does the bank observe about depositor decisions?

  – what do depositors know about position in the withdrawal order?

## Methodology

- Find the efficient allocation of resources (subject to sequential service)
  - impatient depositors all consume at $t = 0$ (and patient depositors at $t = 1$)
  - but they may consume different amounts depending on what the bank knows when they withdraw
- Try to implement this allocation using a direct mechanism
  - "banking contract" allows depositors to choose when to withdraw
  - resembles the demand-deposit arrangements observed in practice
- Question: does this mechanism admit a non-truthtelling equilibrium in which patient depositors withdraw early?
  - if so, we say that banking is *fragile* in that environment

## Peck & Shell (JPE, 2003)

- Depositors report to the bank only when they withdraw
  - bank does not observe decisions of depositors who choose to wait

  $\Rightarrow$ bank chooses a sequence of payments at $t = 0$ : $\left\{x_j\right\}_{j=1}^{I}$

- Depositors have no information about their position in the withdrawal order before deciding
  - all depositors face the same decision problem
  - after decisions are made, places in order assigned at random

- Result: For some parameter values, a bank run equilibrium exists
  - extends Diamond-Dybvig fragility result to an environment where the banking contract is fully optimal

## Green & Lin (JET, 2003)

- All depositors report to the bank at $t = 0$
  - even just to say “I prefer to wait until $t = 1$”
  
  $\Rightarrow$ bank learns about withdrawal demand relatively quickly
  - efficient allocation is more state-contingent than in Peck-Shell

- Depositors observe their position in the order before deciding (or a signal correlated with their position)

- Result: direct mechanism *uniquely* implements the efficient allocation
  - bank run equilibrium never exists

- Suggests proper contracting/regulation can solve the fragility problem
  - no need for government guarantees

# Other contributions

- Early on:
  - Jacklin (1987), Wallace (1988, 1990)

- More recent:
  - Andolfatto, Nosal and Wallace (2007), Ennis and Keister (2009), Azrieli and Peck (2012), Bertolai, Cavalcanti and Monteiro (2014), Sultanum (2014), Andolfatto, Nosal and Sultanum (2014)
  - among others

## Summary so far

- Are optimal banking arrangements fragile?
  - answer depends critically on the details of the environment

  $\Rightarrow$ important to get these details right

- Banking contracts in Green & Lin are very complex
  - do not resemble standard deposits (no "face value")

- Depositors in Peck & Shell are (very) in the dark
  - in equilibrium, some regret their decision when paid by bank

## What we do

- Propose an alternative environment where
  - only depositors who withdraw report to the bank (as in Peck-Shell)
  - depositors observe previous withdrawals (same as bank; new)

- We show that under this specification:

  ($i$) optimal arrangement looks more like a standard banking contract (exhibits a "face value" property in normal times)

  ($ii$) deposits are subject to discounts when withdrawals are high (partial suspension, as in Wallace, 1990)

  ($iii$) banking system **can** be fragile

## Efficient allocation

- Summarized by a payment schedule $\left\{x_j\right\}_{j=1}^{I}$ (as in Peck-Shell)

- Let $\theta =$ number of patient depositors (random)

- Efficient allocation solves:

$$\sum_{\theta=1}^{I} p\left(\theta\right)\left(\sum_{n=1}^{I-\theta} u\left(x_n\right) + \theta u\left(\frac{R z_{I-\theta}}{\theta}\right)\right) + p\left(0\right)\left(\sum_{n=1}^{I-1} u\left(x_n\right) + u\left(z_{I-1}\right)\right)$$

where

$$z_m = I - \sum_{n=1}^{m} x_n \quad \text{for } m = 1, \ldots I-1$$

- Or, recursively:

$$V_n(z_{n-1}) = \max_{\{x_n\}} \left\{ \begin{array}{c} \frac{(x_n)^{1-\gamma}}{1-\gamma} + q_{n+1} V_{n+1}(z_{n-1} - x_n) + \\ \\ (1 - q_{n+1})(I - n) \frac{1}{1-\gamma} \left( \frac{R(z_{n-1} - x_n)}{I-n} \right)^{1-\gamma} \end{array} \right\}$$

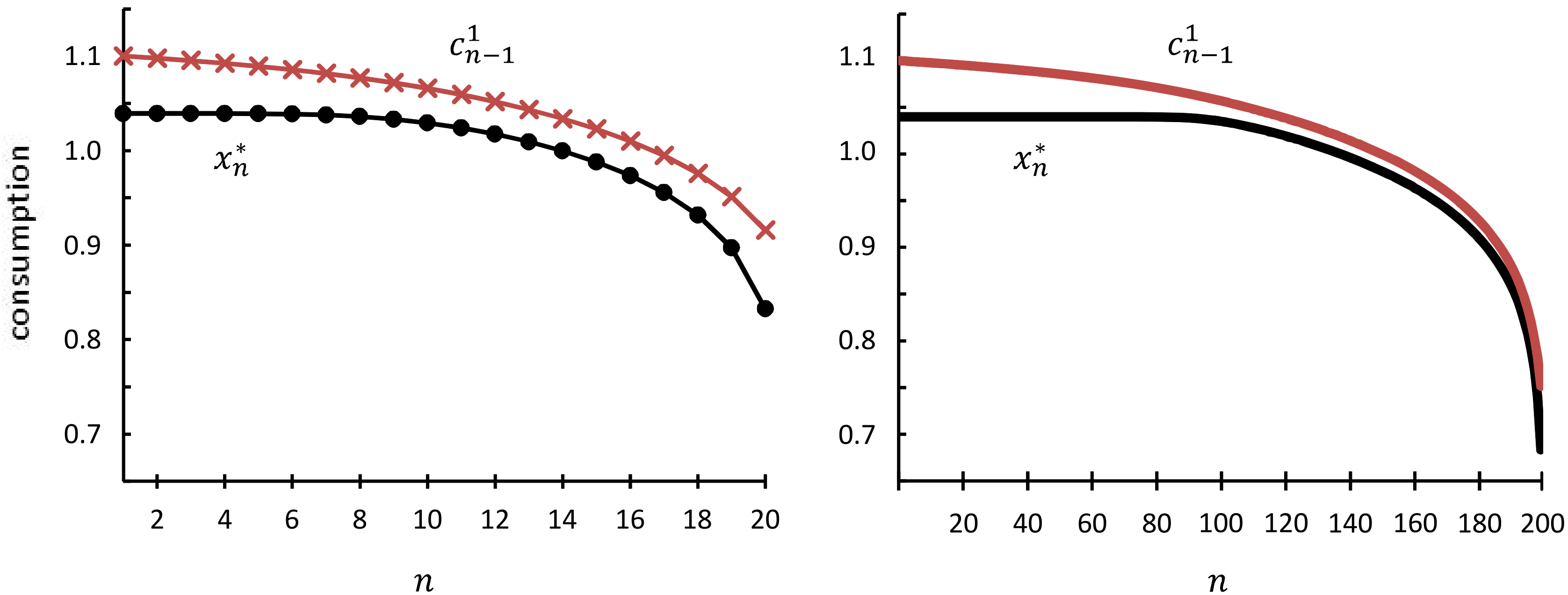
- Solution:

$$x_n^* = \frac{z_{n-1}^*}{(\phi_n)^{\frac{1}{\gamma}} + 1} \text{ for } n = 1, \ldots, I,$$

where

$$\phi_n = q_{n+1} \left( \phi_{n+1}{}^{\frac{1}{\gamma}} + 1 \right)^{\gamma} + (1 - q_{n+1})(I - n)^{\gamma} R^{1-\gamma}$$

- Graphically:




$(a)$ 20 depositors $(b)$ 200 depositors

- Properties:
  - strictly decreasing, but depositors receive "face value" for many $n$
  - liquidity insurance: $x_n > 1$ for many $n$

# Banking: A withdrawal game

- Study the direct mechanism based on $x^*$

- Each depositor observes own type, number of previous withdrawals, then decides when to withdraw

  - a strategy is:

$$y_i : \Omega \times \{1, ..., I\} \to \{0, 1\}$$

- Payoffs in the game are determined as the bank follows $x^*$

- A *Bayesian Nash Equilibrium* is a profile of strategies such that $y_i$ is optimal for all $i$, taking $y_{-i}$ as given

# Incentive compatibility

- Is there a truthtelling (no run) equilibrium with

$$y_i(\omega_i, n) = \omega_i \text{ for all } n?$$

- Define $p_n(\theta; y) =$ posterior probability of $\theta$ for a patient depositor who has the opportunity to make the $n^{th}$ withdrawal
  - complex object: depositor updates about his potential position in the order and the types of other agents

- Patient depositors are willing to always wait if:

$$u(x_n^*) \leq \sum_{\widehat{\theta}=1}^{I} p_n\left(\widehat{\theta}; y_{-i}\right) u\left(R\frac{z_{I-\widehat{\theta}}}{\widehat{\theta}}\right) \quad \text{for } n = 1, \ldots, I.$$

where

$$z_m = I - \sum_{n=1}^{m} x_n.$$

# Financial fragility

- Focus on situations where the efficient allocation is IC

- Ask: Does this game also have a run equilibrium?

- First result: There is no *full run* equilibrium with

$$y_i(\omega_i, n) = 0 \text{ for all } (\omega_i, n) \text{ and all } i$$

  – observing $n = I$ tells the depositor she is last in the order

  $\Rightarrow$ can have $z$ today or $Rz$ tomorrow (with $R > 1$)

  $\Rightarrow$ last depositor will never want to run (as in Green & Lin)

- A run equilibrium, if it exists, is necessarily partial

# A partial run

- One candidate profile of strategies

$$y_i^{\bar{n}}(\omega_i, n) = \begin{cases} 0 & \text{for} \quad n \leq \bar{n} \\ \omega_i & \phantom{\text{for}} \quad n > \bar{n} \end{cases} \quad \text{for some } 1 \leq \bar{n} \leq I - 1 \tag{1}$$

  - run lasts for $\bar{n}$ withdrawals, then stops

- Define:

$$\mu\left(n; y_{-i}^{\bar{n}}\right) = \sum_{\widehat{\theta}=1}^{I} p_n\left(\widehat{\theta}; y_{-i}^{\bar{n}}\right) u\left(R\frac{z_{I-\widehat{\theta}}}{\widehat{\theta}}\right)$$

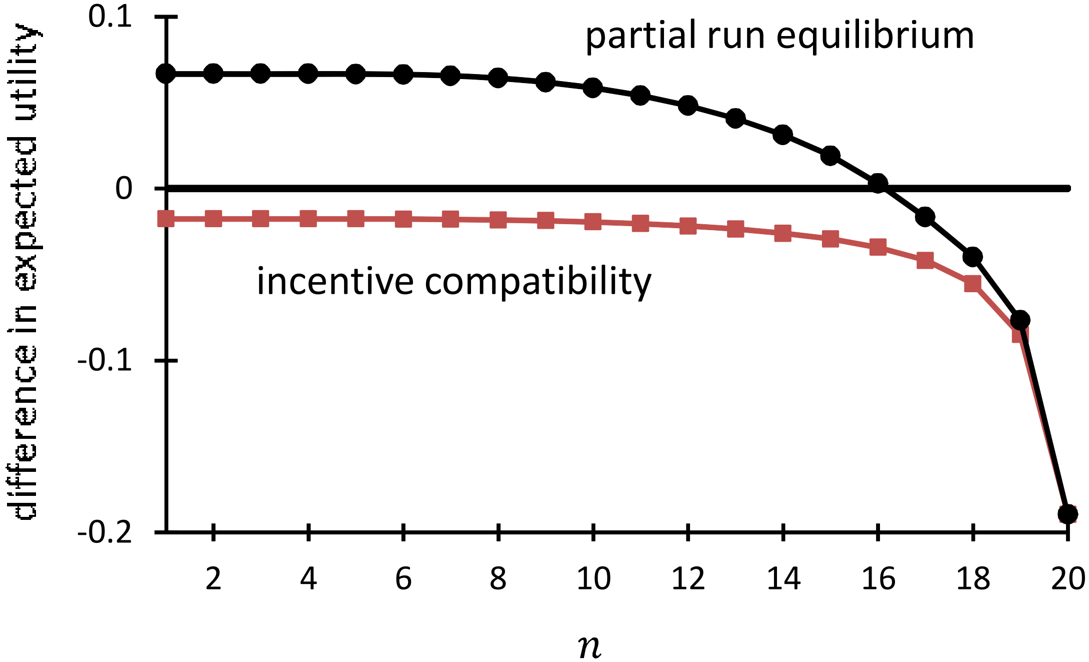
- Need to find $\bar{n}$ such that:

$$\begin{aligned} u\left(x_n^*\right) &\geq \mu\left(n; y_{-i}^{\bar{n}}\right) \quad \text{for } n = 1, \ldots, \bar{n} \\ u\left(x_n^*\right) &\leq \mu\left(n; y_{-i}^{\bar{n}}\right) \quad \text{for } n = \bar{n}+1, \ldots, I \end{aligned}$$

- Many examples can be constructed

# One example

$$I = 20,\ R = 1.1,\ \gamma = 6,\ \pi = \frac{1}{2} \text{ with } \bar{n} = 16$$




black: $u\left(x_n^*\right) - \mu\left(n; y_{-i}^{\bar{n}}\right)$ red: $u\left(x_n^*\right) - \mu\left(n; y_{-i}^{0}\right)$

$\Rightarrow$ Financial fragility can arise under the optimal banking contract here

# Discussion

- If bank expects depositors to run, it should change $\{x_n\}$
  - be more conservative; lower $x_1$, etc.

- But suppose a run is random (determined by "sunspots")
  - if prob(run) is small, bank will set $\{x_n\}$ close to $\{x_n^*\}$

  $\Rightarrow$ a run can occur in some states (Cooper and Ross, 1998)

- Can calculate the maximum probability of a run consistent with equilibrium
  - one way of measuring financial fragility

# Implications

- We are back to the stark policy choice of Diamond & Dybvig
- In a world with incentive distortions...
  - regulation may be desirable to correct distortions
  - but *optimal* regulation (and optimal contracting) may not eliminate bank runs
- What should a policy maker do?
  - need to think about providing government guarantees
  - or living with recurrent (hopefully rare) crises

## Conclusion

- We address the question of whether banking is *inherently* fragile
  - answer is known to depend on the details of the environment
- We propose an environment that generates some nice features
  - banking contract resembles *simple* demand deposits
  - depositors choose between a certain payment today and the risk of waiting
- We show that fragility can arise in this environment
- We believe this approach will be useful in other research
  - in fact, it underpins the limited commitment approach in Ennis & Keister (2010)