Uncertainty Aversion and Systemic Risk

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Financial Crises

- High levels of uncertainty are the hallmark of financial crises.
- Puzzle of Contagion
  - Asian Financial Crisis and Russian Bond Crisis;
  - Subprime MBS and The Great Recession.
- Key Result: Uncertainty Aversion Creates Systemic Risk
  - A significant loss in one asset class generates widespread "pessimism" and "sell-offs."
  - Idiosyncratic Risks can spread generating systemic risk.

Key Drivers

With Uncertainty Averse agents:

- **Endogenous Beliefs:** Holding more of an asset makes you more pessimistic about that asset (portfolio distorted beliefs)
    - Dicks and Fulghieri (2015).
- **Uncertainty Hedging:** Uncertainty-averse investors treat different asset classes as complements.
- **Contagion:** Idiosyncratic shock to one asset class makes investors more pessimistic about other asset classes.

Results

- Diamond-Dybvig with two banks and uncertainty.
- If investors are uncertainty averse, idiosyncratic shock to one bank creates runs on other banks, resulting in systemic risk
- If investors are uncertainty averse,
  1. Less Likely to Run One Bank,
  2. All Runs are Systemic,
  3. Contagion across Markets,
  4. Contagion depends on degree of uncertainty:
     - Small Uncertainty: Local Shocks stay Local
     - Moderate Uncertainty: Shocks Spread
     - Large Uncertainty: Shock Spread with :"Flight to Quality" and "Lending Freezes."

Existing Literature on Contagion

- Kodres and Pritsker (2002): Portfolio rebalancing
  - Contagion is due to exposure to shared macroeconomic factors
- Allen and Gale (2010): Structure of Interbank Market
  - Limited Ability to Insure against Idiosyncratic Shocks
- Caballero and Krishnamurthy (2008):with Uncertainty Aversion
  - Balance Sheet Mechanism
  - Uncertainty Aversion Amplifies Shocks
- Our paper: Uncertainty Aversion *itself* causes Systemic Risk
  - Idiosyncratic Shocks spread to other markets
  - New result of our paper

Ellsberg Paradox

- Urn K contains 100 Balls:
  - 50 Blue and 50 Red.
- Urn U contains 100 Balls:
  - Only Blue and Red, unknown proportion.
- Which Urn (K or U) would you prefer?
  - CHOICE #1: $100 if Blue is drawn.
  - CHOICE #2: $100 is Red is drawn.
- Most choose Urn K for both lotteries.

What Drives the Ellsberg Paradox?

- Asymmetric Information:
  - Is the researcher out to get you?
  - Better answer: Nature is out to get you!
- Murphy's Law:
  - Instead of one prior, an agent has multiple priors;
  - Takes worst-case scenario over possible priors;
  - Average over what you know, worry about what you don't.

Models of Uncertainty Aversion

- Subjective Expected Utility: single prior μ
  - $U^e = E_\mu [u(w)]$.
- Minimum Expected Utility:
  - Follows from the Uncertainty Aversion Axiom:
    - $f \sim g \Rightarrow \alpha f + (1-\alpha) g \succ f$.
  - Agents have a set of priors $\mathcal{M}$, with $\mu \in \mathcal{M}$:
  - $U^a = \min_{\mu \in \mathcal{M}} E_\mu [u(w)]$.

Uncertainty Aversion in Finance

- Equity Premium Puzzle:
  - Risk-Free Rate Puzzle;
  - Maenhout (2004).
- Local Bias Puzzle:
  - Kirabaeva (2009)
- Nonparticipation Puzzle:
  - Easley - O'Hara (2009), Requires Heterogeneity;
  - Easley - O'Hara (2013) applies to Microstructure.

Uncertainty Aversion in Finance (2)

- Macrofinance:
  - Colacito and Croce (2012).
- Corporate Finance:
  - Garlappi, Giammarino, and Lazrak (2013);
  - Dicks and Fulghieri (2015).
- Amplification Mechanism:
  - Caballero and Krishnamurthy (2008);
  - Krishnamurthy (2010).

Uncertainty-Hedging Demand:

Theorem (1)

Ambiguity-averse agents prefer uncertainty-hedging:

$$q \min_{\mu \in \mathcal{M}} E_{\mu}\left[u\left(y_1\right)\right] + (1-q) \min_{\mu \in \mathcal{M}} E_{\mu}\left[u\left(y_2\right)\right] \leq \min_{\mu \in \mathcal{M}} \left\{ q E_{\mu}\left[u\left(y_1\right)\right] + (1-q) E_{\mu}\left[u\left(y_2\right)\right] \right\}, \quad \text{for all } q \in [0,1].$$

- Investor more optimistic about portfolios than single assets.
- Analog of "benefits of diversification" under uncertainty.
- If agents are SEU, this holds as an equality.

Timing

- Extension of Diamond and Dybvig (1983).
- Investors and Two Banks:
  - Banks are benevolent;
  - Bank τ has exclusive access to type τ assets.
- $t = 0$, Banks contract with Investors;
- $t = 1$, Liquidity Shock Realized;
- $t = 2$, Payoffs realized.

Risky Technology

- Our Asset Structure:
- Early Liquidation Option;
- Risk:

$$\begin{array}{cccc} t=0 & t=1 & & t=2 \\ & \left\{\begin{array}{c} 1 \\ 0 \\ \\ \end{array}\right. & & 0 \\ -1 & & \left\{\begin{array}{c} R \\ 0 \end{array}\right. & \begin{array}{r} p_{\tau}(\theta) \\ 1-p_{\tau}(\theta) \end{array} \end{array}$$

Liquidity Shock

- Continuum of investors, identical at time $t = 0$, each with \$2.
- At $t = 1$, investors learn their type:
    - Fraction λ are affected
        - Early Investors, utility $u(c_1)$
    - Fraction $(1 - \lambda)$ unaffected
        - Late Investors, utility c_2.
- Investors' types are not observable.

Asset Types

- Three classes of assets:
  - storage technology (numeraire);
  - type τ assets, $\tau \in \{A, B\}$:
    - A and B have different exposure to source of uncertainty.
    - Bank τ has exclusive access to type τ assets.
- Type τ asset pays \$$R$ at $t = 2$ with probability $p_\tau(\theta)$, else 0:

$$p_A(\theta) = e^{\theta - \theta_1}, p_B(\theta) = e^{\theta_0 - \theta}$$

$=>$ Increasing θ good for A, bad for B.

- θ is ambiguous. $\theta \in C = \left[\hat{\theta}_0, \hat{\theta}_1\right] \subset [\theta_0, \theta_1]$.
  - $\theta^e - \hat{\theta}_0 = \hat{\theta}_1 - \theta^e$, where $\theta^e = \frac{1}{2}(\theta_0 + \theta_1)$.

Contracts

- Bank τ offers the contract $d_\tau = \{d_{1\tau}, d_{2\tau}^s, d_{2\tau}^r\}$.
- Promises $d_{1\tau}$ to those who withdraw early
- In equilibrium, investors invest equally in banks.
- Objective Function:

$$U_0 = \lambda u\left(d_{1A} + d_{1B}\right) + (1-\lambda)\, U_L\left(\theta_L\right),$$

where

$$U_L\left(\theta\right) = d_{2A}^s + d_{2B}^s + e^{\theta-\theta_1} R d_{2A}^r + e^{\theta_0-\theta} R d_{2B}^r .$$

Portfolio-Distorted Beliefs

With the portfolio $\Pi = \{d^r_{2A}, d^r_{2B}, d^s_{2A} + d^s_{2B}\}$, let

$$\theta^a(\Pi) = \arg\min_{\theta \in C} U_L(\theta)$$

Lemma (1)

Let

$$\tilde{\theta}^a(\Pi) \equiv \frac{1}{2}(\theta_0 + \theta_1) + \frac{1}{2}\ln\frac{d^r_{2B}}{d^r_{2A}}$$

Beliefs held by an uncertainty averse agent are:

$$\theta^a(\Pi) = \begin{cases} \hat{\theta}_0 & \tilde{\theta}^a(\Pi) \leq \hat{\theta}_0 \\ \tilde{\theta}^a(\Pi) & \tilde{\theta}^a(\Pi) \in (\hat{\theta}_0, \hat{\theta}_1) \\ \hat{\theta}_1 & \tilde{\theta}^a(\Pi) \geq \hat{\theta}_1 \end{cases}.$$

Portfolio-Distorted Beliefs (2)

Lemma (2)

Holding type-τ assets constant, a decrease in an investor's holding in type-τ' assets, $d^r_{2\tau'}$ with $\tau' \neq \tau$, makes the investor more pessimistic about type-τ assets, for $\tau \in \{A, B\}$. In addition, portfolio-distorted beliefs are homogeneous of degree zero in the holding of the risky assets, $\{d^r_{2A}, d^r_{2B}\}$.

Constraints

- Investors prefer not running both banks:

$$U_L\left(\theta^a\right) \geq d_{1A} + d_{1B}.$$

- Investors prefer not running only Bank A :

$$U_L\left(\theta^a\right) \geq d_{1A} + d_{2B}^s + e^{\theta_0 - \hat{\theta}_1} R d_{2B}^r,$$

- Investors prefer not running only Bank B :

$$U_L\left(\theta^a\right) \geq d_{1B} + d_{2A}^s + e^{\hat{\theta}_0 - \theta_1} R d_{2A}^r.$$

- Budget Constraint:

$$\lambda d_{1\tau} + (1-\lambda)\left[d_{2\tau}^s + d_{2\tau}^r\right] \leq 1.$$

Assumptions

- Profitability: $e^{\theta^e - \theta_1} R > 1$.
- Uncertainty: $e^{\hat{\theta}_0 - \theta_1} R < 1$.
- Regularity (A_0):

$$u'(2) > e^{\theta^e - \theta_1} R > u'\left(2 \frac{e^{\theta^e - \theta_1} R}{\lambda e^{\theta^e - \theta_1} R + (1 - \lambda)} \right).$$

Investors SEU

Theorem (2)

If investors are uncertainty neutral, the optimal deposit contract, $d_\tau^{R*} \equiv \{d_{1\tau}^*, d_{2\tau}^{s*}, d_{2\tau}^{r*}\}$, has:

$$d_{2\tau}^{s*} = 0, \quad 1 < d_{1\tau}^* < e^{\theta^e - \theta_1} R d_{2\tau}^{r*}, \quad \text{for } \tau \in \{A, B\},$$

that is, banks provide partial insurance against liquidity shocks and are exposed to runs. Finally, it is WLOG optimal for investors to invest equally in both banks.

- Because $d_{1\tau} > 1$, runs are possible;
- Runs not necessarily systemic.

Theorem 3

- If investors are uncertainty averse and (A_1) holds, there are multiply equilbria
  - "Risky" equilibrium as in Theorem 2;
  - "Safe" equilibrium ("lending freeze"), $d_{1\tau} = d^s_{2\tau} = 1$, $d^r_{2\tau} = 0$: Banks invest only in the safe technology and offer only safe deposit contracts.
- Investors optimally invest equally in both banks.

1. The "risky" equilibrium P-dominates the "safe" equilibrium;
2. Runs are not possible in the "safe" equilibrium, but runs are possible in the "risky" equilibrium;
3. All runs will be systemic.

Three types of runs

- Panic Runs (DD): Coordination Failure:
  - Bank would be solvent if no one runs.
- Fundamental Runs:
  - Unprofitable to remain in bank even if no one else runs.
- Uncertainty-Based Systemic Runs:
  - No bad news about this bank,
  - Idiosyncratic bad news about other banks spreads to this bank.

Interim Information

- At $t = 1$, a public signal is observed.
- With probability ε, bad news about bank τ.
  - Success payoff of type τ assets drops to ϕR, where $\phi < 1$.
- With probability $1 - 2\varepsilon$, no bad news.
- Utility:

$$u(w) = \begin{cases} \psi w & w \leq \tilde{c} \\ \psi \tilde{c} + (w - \tilde{c}) & w > \tilde{c} \end{cases} \tag{1}$$

where $\psi > e^{\theta^e - \theta_1} R$ and $\tilde{c} \in \left(2, 2\frac{e^{\theta^e - \theta_1} R}{\lambda e^{\theta^e - \theta_1} R + (1-\lambda)}\right)$.

Results (Theorem 5)

- Uncertainty Averse Investors are Slower to Run a Given Bank;
- All Runs will be Systemic;
- Idiosyncratic Shocks produce Systemic Runs;
- Uncertainty-Based Systemic Run is new to literature.

Contagion Across Markets

- A stock company has exclusive access to type-B assets. Firm A is still a "bank."

Lemma (4)

The stock company implements incentive-compatible cash flow of $\{\Delta_{1B}, \sigma_{2B}, \rho_{2B}\}$ *by setting* $\Delta_{1B} = \lambda d_{1B}$, $\sigma_{2B} = (1-\lambda)\, d^s_{2B}$, *and* $\rho_{2B} = (1-\lambda)\, d^r_{2B}$. *Late investors use the dividend to buy shares from the late consumers for price* $P_{1B} = (1-\lambda) d_{1B}$.

- *If investors are uncertainty neutral, the "risky" equilibrium will be implemented.*
- *If investors are uncertainty averse, there are both the "safe" equilibrium and the "risky" equilibrium.*

Contagion Across Markets (2)

Theorem (6)

Idiosyncratic risk leads to systemic risk iff investors are uncertainty averse. That is, bad news about the bank harms the market value of the stock, and bad news about the stock can produce a run on the bank.

- New channel for contagion: investor preferences.
- Bank runs lead to runs on other assets
  - "Breaking the Buck"
- Stock market crash can lead to bank runs and a "Flight to Quality"

Degree of Uncertainty

- Let $\alpha = \theta^e - \hat{\theta}_0$.

Theorem (7)

There are critical values $\{\underline{\alpha}, \bar{\alpha}\}$ such that

1. *for $\alpha \leq \underline{\alpha}$ the only equilibrium is the "risky equilibrium," and there is no contagion;*
2. *If $\underline{\alpha} < \alpha < \bar{\alpha}$ the only equilibrium is the "risky equilibrium," but there is contagion and runs are systemic;*
3. *If $\alpha \geq \bar{\alpha}$, there both "risky" equilibria, with contagion and systemic runs, and "safe" equilibria with a "lending freeze."*

Multiple Banks

- Section 6 extends model to setting with
  - Multiple Banks
  - Aggregate Uncertainty.
- Results unchanged.

Empirical Implications

- Different Asset Classes are Complements under Uncertainty Aversion (risk diversification vs uncertainty hedging).
- In times of uncertainty, financial crises will spread with a deterioration of investor sentiment and lending freezes.
- Investors will be slower to run if uncertainty averse, but runs will be systemic.
- Mechanism applies across asset classes and markets:
    - Direct Effect vs indirect effects.

Policy Implications

- Uncertainty Aversion Leads to Fragility;
  - Transparency of Regulator could bring stability.
- Bailouts: If the shock is big enough, must bail out all banks to avert a crisis.
- Asset Sales: The Fed should purchase distressed assets from the unaffected bank:
- Volcker Rule:
  - Destroys the risky equilibrium : Safe Equilibrium is Pareto inferior.

Conclusion

- New Theory of Systemic Risk based on Uncertainty Aversion.
- Uncertainty Aversion Independently Causes Contagion;
  - We are the first to show this.
- Financial System fragility depends on level of uncertainty.