Potential Buyers and Fire Sales in Financial Networks

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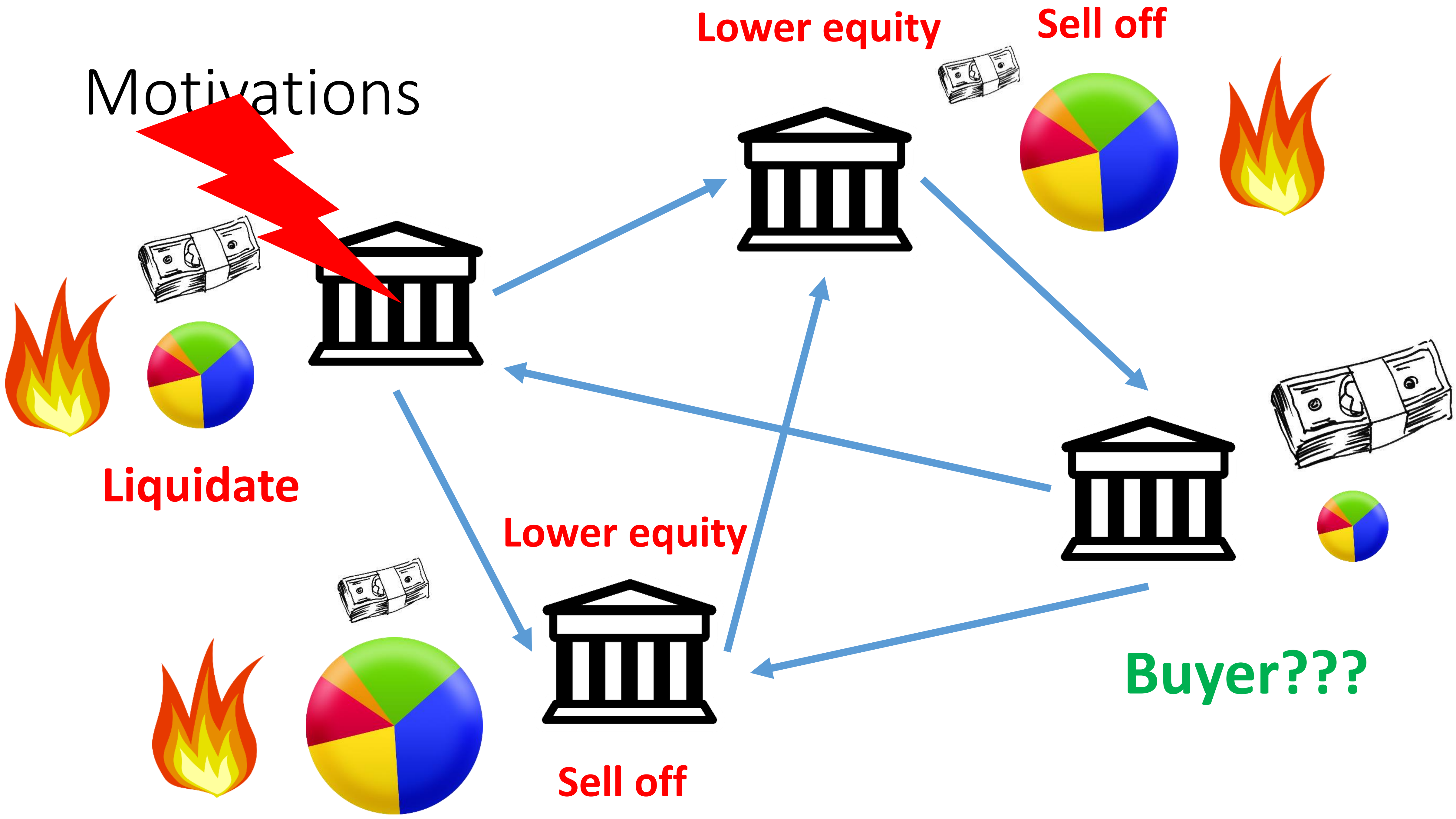
Motivations



Motivations (2)

- Banks hold liquid and illiquid assets
  - Liquid ~ low risk & low return
  - Illiquid ~ high risk & high return
- Banks are risk averse and adjust their asset portfolios to maximize risk-adjusted returns

- A financial system that tends to keep some potential buyers untouched can be a solution to the fire sale problem
- This *self-rescue* feature avoids seeking for help from outsider such as government or central bank → reduce burden on taxpayers

Related Literature

- Shleifer and Vishny (1992, 2011): potential buyers do not function during crises → having to sell to *non-specialists* at fire sale prices
- Acharya and Yorulmazer (2008): bail out policy encourages banks to herd → increases the risk of bank failure
- Acharya, Shin and Yorumazer (2011): providing capital to surviving banks conditional on their liquid holdings encourages banks to hold more liquid assets

- We suggest a policy that leads to a self-rescue system

Related Literature (2)

- Interbank liability → network topology
  - Eisenberg and Noe (2001), Gai and Kapadia (2010), Acemuglu, Ozdaglar and Tahbaz-Salehi (2015), Demange (2016)
- Interbank liability and asset fire sell → liquidity constraints
  - Cifuentes, Ferrucci, Shin (2005), Chen, Liu and Yao (2016), Cecchetti, Rocco and Sigalotti (2016), and Feinstein (2017)
- Illiquid asset sales → target leverage ratio
  - Greenwood, Landier and Thesmar (2015)

- We consider banks optimizing their asset holdings which can be both sellers and buyers

Model: Banking Network

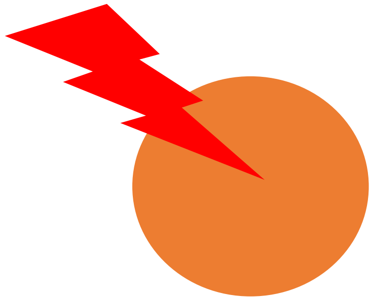
- Three-period financial network with N banks
- Time 0: Bank i's balance sheet

Interbank loan & liability mature at time 1

Asset	Liability + Equity
Interbank loan $l_{j,i}, j = 1, \dots, N$	Interbank liability $l_{i,j}, j = 1, \dots, N$
Cash (liquid asset) c_i	Deposit d_i
Loans (illiquid assets) $\theta_{i,k}, k = 1, \dots, K$	Equity

K types of loans
Mature at time 2
Face value of \$1
Loans may default

Model: Banking Network (2)



- <u>Time 1</u>: A shock arrives:
  - Bank shock: fraud or litigation cost of size v_i
  - Asset shock: increase in default probability of type-k loan

- Repay interbank liabilities: given loan price vector $p = [p_1, \dots, p_K]'$

$$x_{i,j} = \frac{l_{i,j}}{L_i} \min\left\{L_i, c_i + \sum_{k=1}^{K} p_k \theta_{i,k} + \sum_{u \neq i}^{N} x_{u,i} - v_i\right\}, \qquad i,j = 1, \dots, N$$

where $L_i = d_i + \sum_{j \neq i}^{N} l_{i,j}$.

- Bank i is solvent if $x_{i,j} = l_{i,j}, j = 1, \dots, N$.

Model: Banking Network (3)

- Time 1 (cont.):
- Trade illiquid loans: given $p = [p_k], x = [x_{i,j}]$, solvent bank i maximizes mean-variance utility of return on equality (ROE)

$$\max_{\hat{\theta}} \quad E[ROE_i] - \frac{\gamma_i}{2} Var(ROE_i)$$

$$\text{subject to} \quad \sum_{k=1}^{K} p_k \hat{\theta}_{i,k} \leq e_i + d_i$$

$$\hat{\theta}_{i,k} \geq 0, k = 1, \ldots, K$$

Model: Banking Network (4)

- <u>Time 1 (cont.)</u>:
- ROE of bank i

Payoff of portfolio of type-k loans

Managing cost

$$ROE_i = \sum_{k=1}^{K} \left(\tilde{R}_{i,k}(\hat{\theta}_{i,k}) - p_k \hat{\theta}_{i,k} - f_{i,k} \hat{\theta}_{i,k} \right) / e_i$$

where equity

$$e_i = c_i + \sum_{k=1}^{K} p_k \theta_{i,k} + \sum_{u \neq i}^{N} x_{u,i} - v_i - d_i - \sum_{u \neq i}^{N} l_{i,u} = \bar{c}_i + \sum_{k=1}^{K} p_k \theta_{i,k}$$

- Equilibrium price vector p:

$$\sum_{i=1}^{N} \theta_{i,k} = \sum_{i=1}^{N} \hat{\theta}_{i,k}, \qquad k = 1, \ldots, K$$

Model: Default Payoff Distribution

- Time 2: Loan payoff is realized
- Each type-k loan pays

$$\tilde{r}_{m,k} = \begin{cases} 1 & \text{with prob } 1 - \lambda_k \\ 0 & \text{with prob } \quad \lambda_k \end{cases}$$

- The portfolio value of type-k loans is

$$\tilde{R}_{i,k}(\hat{\theta}_{i,k}) = \sum_{m=1}^{\hat{\theta}_{i,k}} \tilde{r}_{m,k}$$

- Default correlations are modeled by *Gaussian copula*.

Bank Optimal Portfolios

- <u>One type of loans:</u>

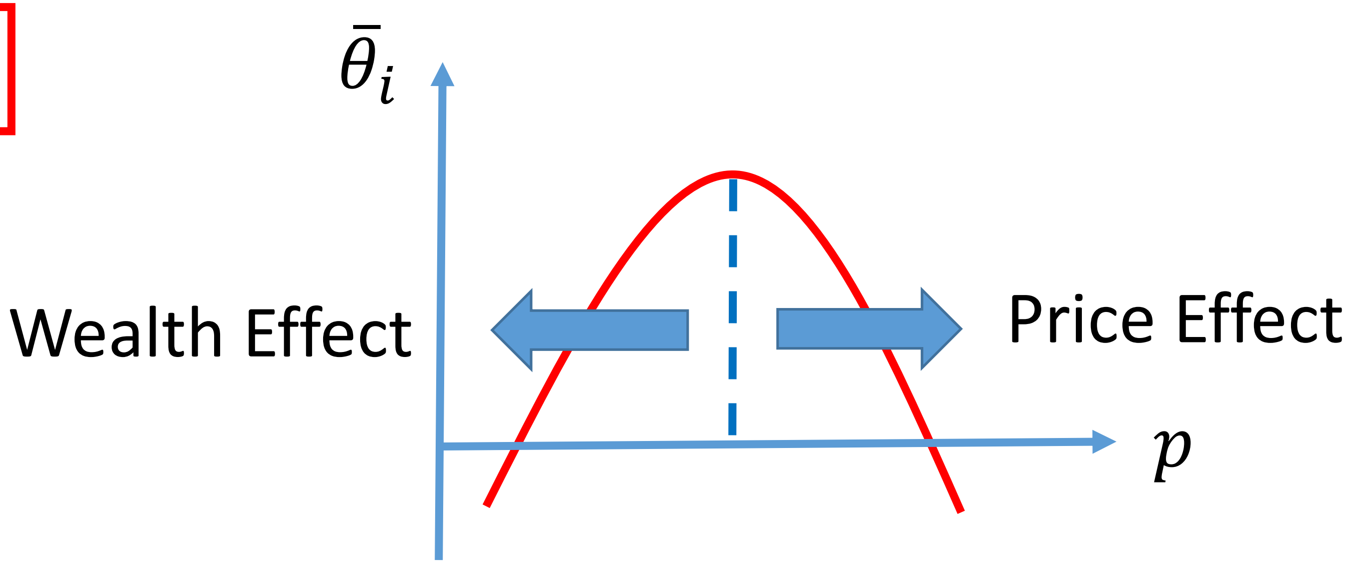
Equity

Mean-Variance

Negative adjustment

$$\bar{\theta}_i = \frac{(\bar{c}_i + p\theta_i)}{\gamma_i}\left(\frac{1-\lambda-p-f_i}{\psi-(1-\lambda)^2}\right) - \frac{1}{2}\left(\frac{1-\lambda-\psi}{\psi-(1-\lambda)^2}\right)$$

Risk aversion



Bank Optimal Portfolios (2)

$\eta_{1,2} = 0$
if default correlation
of different loan types is zero

- Two types of loans:

$$\theta^*_{i,1} \propto \bar{\theta}_{i,1} - \eta_{1,2}(\psi_2 - (1-\lambda_2)^2)\bar{\theta}_{i,2}$$

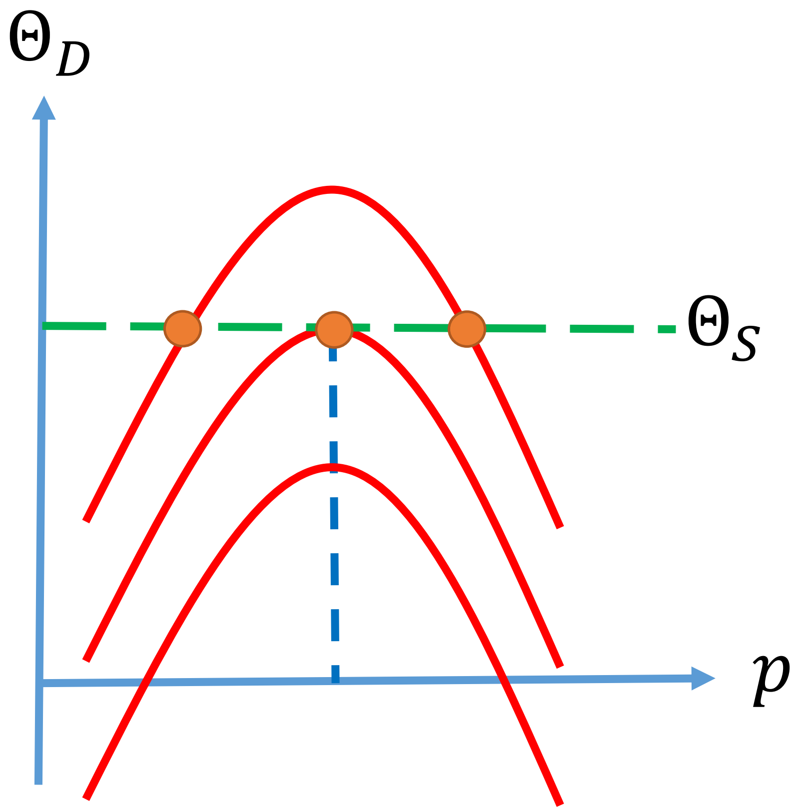
Substitution effect

- Optimal holding:

$$(\hat{\theta}_{i,1}, \hat{\theta}_{i,2}) = \begin{cases} (\theta^*_{i,1}, \theta^*_{i,2}) & \text{if} \quad \theta^*_{i,1} > 0, \theta^*_{i,2} > 0 \\ (\bar{\theta}_{i,1}, 0) & \text{if} \quad \theta^*_{i,1} > 0, \theta^*_{i,2} \leq 0 \\ (0, \bar{\theta}_{i,2}) & \text{if} \quad \theta^*_{i,1} \leq 0, \theta^*_{i,2} > 0 \\ (0,0) & \text{if} \quad \theta^*_{i,1} \leq 0, \theta^*_{i,2} \leq 0 \end{cases}$$

Equilibrium: One Asset

- <u>Assumptions</u>:
  - One type of loans: $K = 1$
  - Equal cost: $f_i \equiv f$
  - Full repayment without shock: $X = L$
- <u>Before shocks</u>:
- We may have two equilibrium prices,
  unique equilibrium price,
  or no equilibrium price.
- We assume that at least one equilibrium exists.



Equilibrium: One Asset (2)

- Before shock (cont.):
- We focus on the equilibrium that could lead to fire sales

Riskiness: increasing in λ

$$p \approx 1 - \lambda - f - \frac{U}{\sum_{i=1}^{N} \frac{\theta_i}{\gamma_i}(1 - \lambda - f) + \sum_{i=1}^{N} \frac{\bar{c}_i}{\gamma_i}}$$

Expected payoff after cost

Risk-aversion-adjusted wealth $\approx \sum_{i=1}^{N} e_i/\gamma_i$

Equilibrium: One Asset (3)

- <u>After a bank shock</u>:
  - A small shock of size v_j hits bank j
  - No insolvent banks

$$p(v_j) \approx 1 - \lambda - f - \frac{U}{\sum_{i=1}^{N} \frac{\theta_i}{\gamma_i}(1 - \lambda - f) + \sum_{i=1}^{N} \frac{\bar{c}_i}{\gamma_i} - \frac{v_j}{\gamma_j}}$$

- A small shock hitting an *aggressive* bank (low γ_j) makes bigger impact than hitting a *conservative* bank (high γ_j).

Equilibrium: One Asset (4)

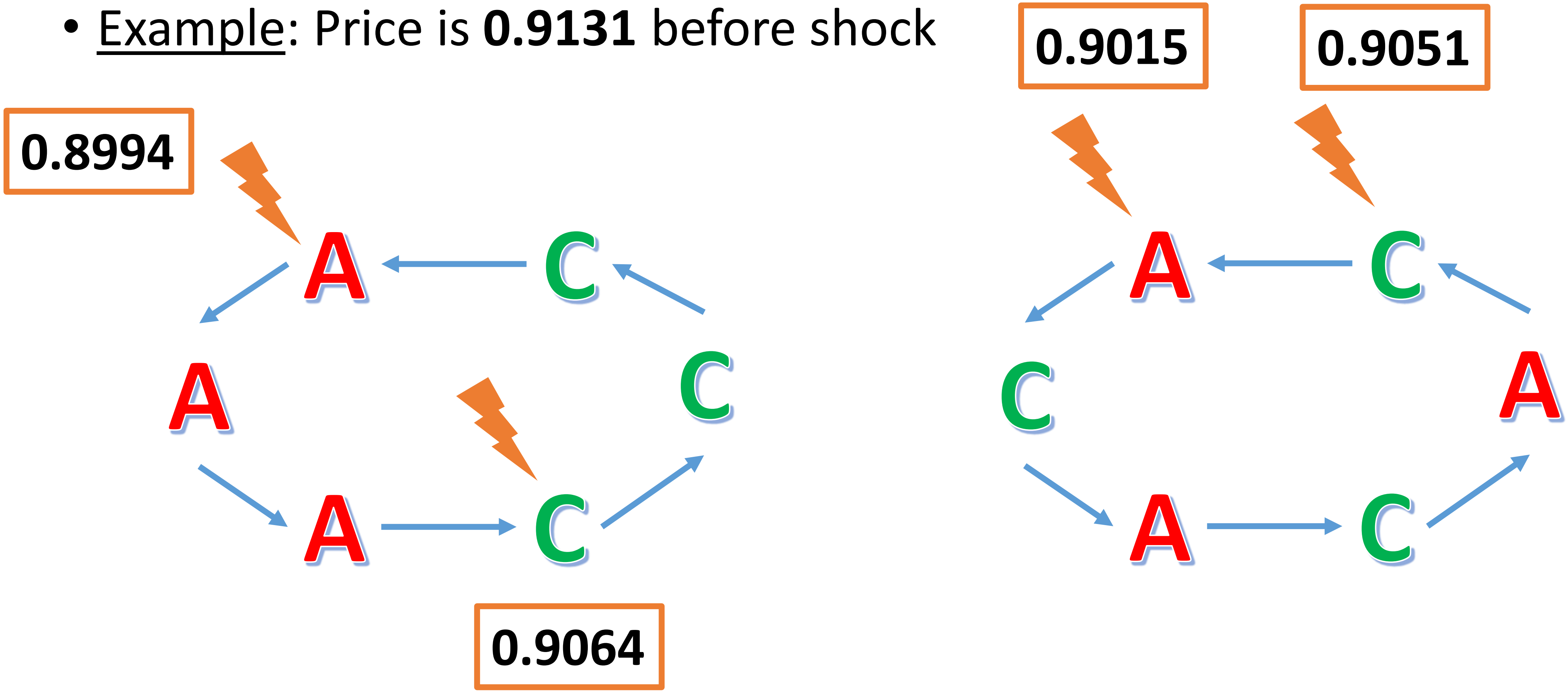
- <u>After a bank shock (cont.)</u>:
  - A larger shock of size v_j hits bank j
  - Only bank j is insolvent

$$p(v_j) \approx 1 - \lambda - f - \frac{U}{\sum_{i \neq j}^{N} \frac{\theta_i}{\gamma_i}(1 - \lambda - f) + \sum_{i \neq j}^{N} \frac{\bar{c}_i}{\gamma_i} - \sum_{i \neq j}^{N} \frac{l_{j,i}}{\gamma_j} \min\left\{\frac{v_j - (\theta_j p(v_j) + \bar{c}_j)}{L_j}, 1\right\}}$$

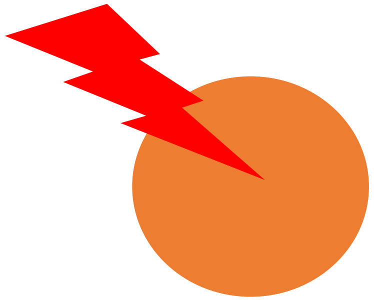
- Large interbank liabilities between aggressive banks *amplify* fire sales

Equilibrium: One Asset (5)

- <u>Example</u>: Price is **0.9131** before shock



Equilibrium: One Asset (6)



- After an asset shock:
  - Default probability increases from λ to λ'

Larger riskiness

$$p \approx 1 - \lambda' - f - \frac{U'}{\sum_{i=1}^{N} \frac{\theta_i}{\gamma_i}(1 - \lambda' - f) + \sum_{i=1}^{N} \frac{\bar{c}_i}{\gamma_i}}$$

Lower expected payoff

Lower risk-aversion-adjusted wealth

- The first insolvent bank is the bank with highest θ_i / e_i: *critical bank*.
- Liabilities between critical bank and aggressive banks *amplify* fire sale.

Equilibrium: Two Assets – Equal Cost

- Assumptions:
  - Two types of loans: $K = 2$
  - Equal cost: $f_{i,1} \equiv f_1$ and $f_{i,2} \equiv f_2$
  - Full repayment without shock: $X = L$

- Before shocks:
- At each equilibrium $p = [p_1, p_2]'$

Expected profit per unit risk is the same.

$$\frac{1 - \lambda_1 - f_1 - p_1}{U_1} = \frac{1 - \lambda_2 - f_2 - p_2}{U_2}$$

Riskiness of type-1 loans depends on λ_2 if correlation is not zero.

Equilibrium: Two Assets – Equal Cost (2)

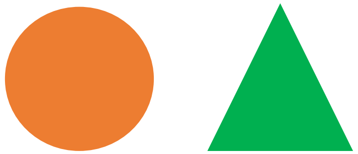
- <u>After a bank shock</u>:
- Price of loan type with higher level of riskiness is more sensitive to a bank shock.

$$\Delta p_1 = \frac{U_1}{U_2} \Delta p_2$$

- <u>After an asset shock</u>:
- Cross-asset contagion through the wealth effect

- When default correlation is positive, the cross-asset contagion effect can be more or less due to a smaller or larger substitution effect.

Equilibrium: Two Assets – Bank Expertise



- <u>Assumptions</u>:
  - Two types of loans: $K = 2$
  - Two sectors: $f_{i,1} \equiv 0$ and $f_{i,2} \equiv f_2$ for i in sector 1

    $f_{i,1} \equiv f_1$ and $f_{i,2} \equiv 0$ for i in sector 2
  - Full repayment without shock: $X = L$

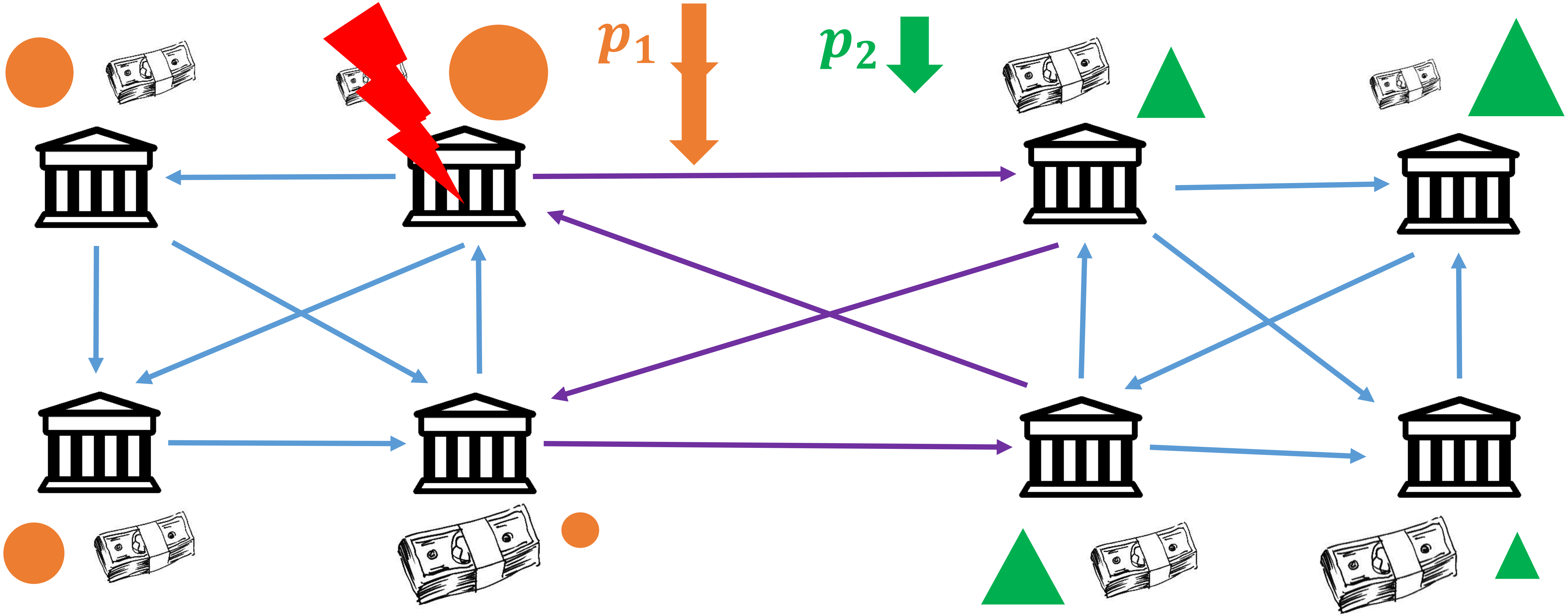
- <u>Before shocks</u>:
- From no cross-sector holdings, the loan markets are decoupled:

$$\left(\hat{\theta}_{i,1}, \hat{\theta}_{i,2}\right) = \left(\bar{\theta}_{i,1}, 0\right) \text{ for } i \text{ in sector 1}$$

$$\left(\hat{\theta}_{i,1}, \hat{\theta}_{i,2}\right) = \left(0, \bar{\theta}_{i,2}\right) \text{ for } i \text{ in sector 2}$$

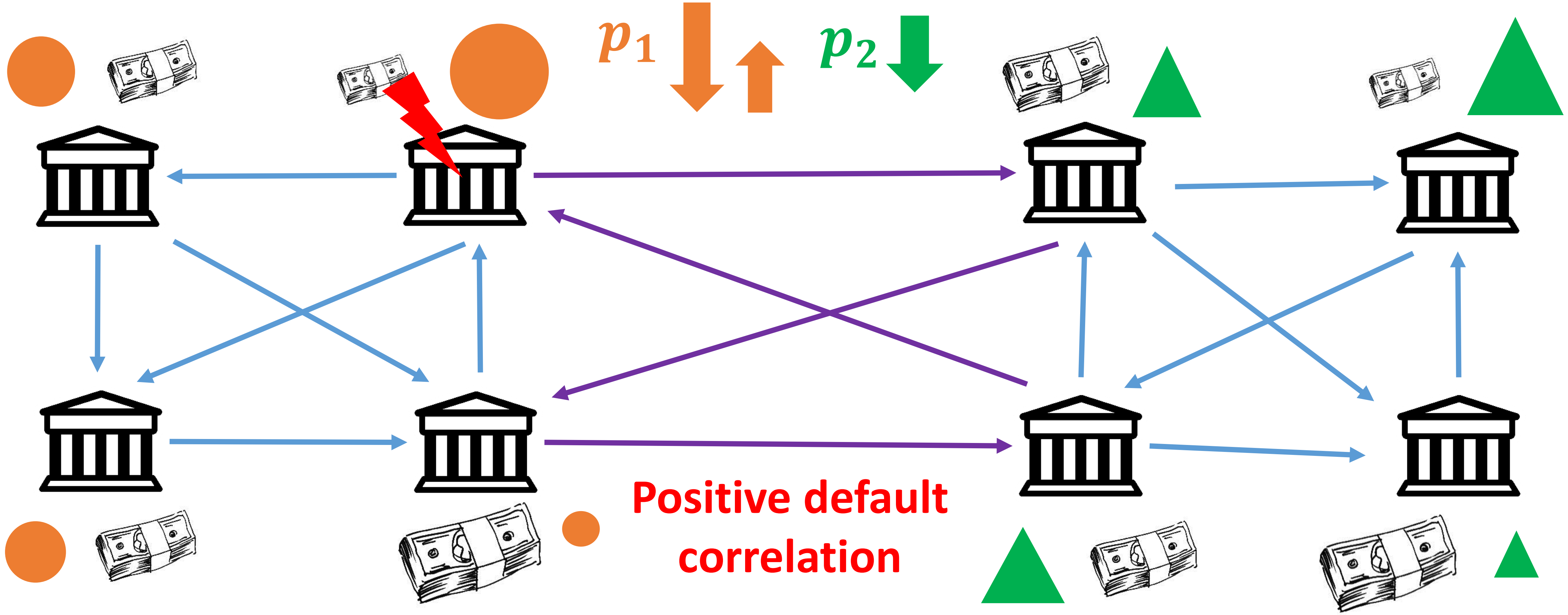
Equilibrium: Two Assets – Bank Expertise (3)

- <u>After a bank shock</u>: prices are still expensive after shock



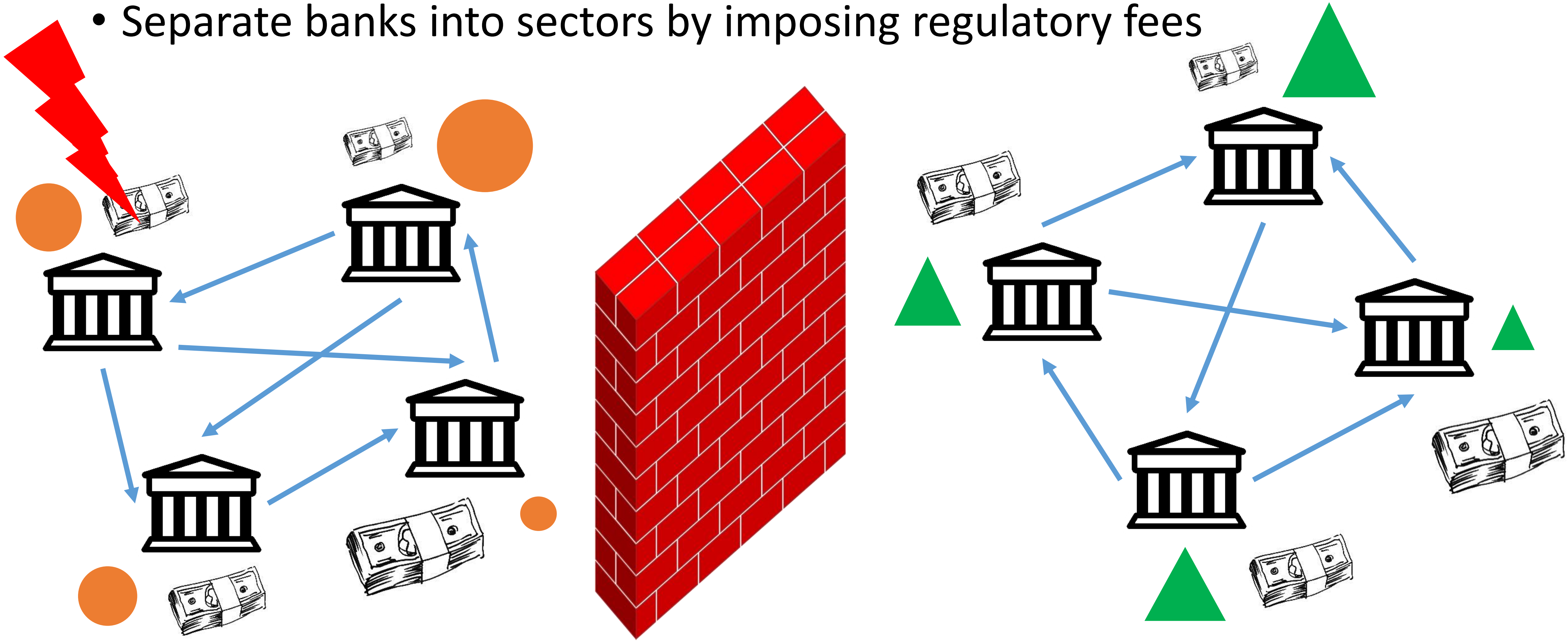
Equilibrium: Two Assets – Bank Expertise (3)

- <u>After a bank shock</u>: price becomes cheap after shock



Policy Implications

- Separate banks into sectors by imposing regulatory fees



Conclusions

- Aggressive banks are helpful as good potential buyers, but harmful as risk amplifiers
- Appropriate interbank network can strengthen the system’s stability
- Existence of potential buyers is an important determinant of fire sales
- We propose a policy to create self-rescue system by dividing banks into sectors to limit common exposures and hence avoid unexpected contagion during good times, and allow banks to act as secondary potential buyers of other sectors during bad times.
- We will extend our work to include external buyers and empirical studies