An Anatomy of the Repo Market Crash

Wei Qiao (Penn State)

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REPO CONTRACT – REPURCHASE AGREEMENT

- Repo: a form of collateralized and short-term borrowing contract
- Year-end gross outstanding at 2007 estimated as $10 trillion for repo
- Central to the wholesale banking sector: largest financial sector in recent years
- Deep connection with residential mortgages: largest part of the household debt
- Repo rate is an important anchor for many other interest rates: has large impact on the investment behaviors of firms

CRASH ON THE REPO MARKET: FROM GORTON (2010)

Hair-cut: percentage devaluation of an asset when it is used as collateral

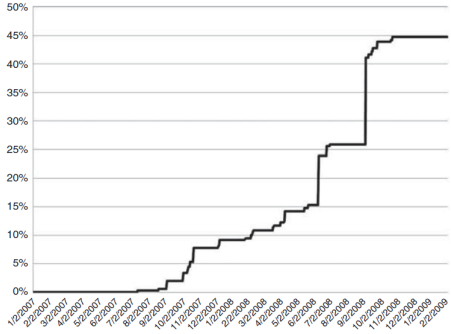

FIGURE 2.12 Average Repo Haircut on Structured Debt. Source: Dealer Bank.

THREE EXPLANATIONS

- Price of RMBS: housing price decline + design of the RMBS
- Liquidity of RMBS: asymmetric information between RMBS sellers and buyers
- (Shadow) bank Run: strategic complementarities among repo lenders

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RESEARCH QUESTION

Quantitatively investigate and decompose the contribution of the three explanations

WHY

- Different policy implications
  - Price: costly to bail out, design of RMBS (incentive structure of the shadow banking system)
  - Liquidity: optimal to bail out, QE, credit rating and information disclosure policy, centralized market
  - Bank Run: lender of the last resort (guarantee programs), reserve ratio, deposit insurance
- Roles of explanations may be different across different stages of the crisis: timing of the policy intervention
- Evaluation of policy response: LSAP initiated by Fed

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WHY NOT

- Data limitation
- Three explanations are inter-woven with each other
  - prices and liquidities
  - collaterals are required to mark to markets
  - serial correlations: endogenous evolution of the balance sheet condition of repo borrowers
- Existing models are not designed for my research question
  - price explanation requires the model to be stochastic
  - capturing the liquidity explanation need heterogeneity in assets
  - model has to be dynamic to keep track of the balance sheet evolution of buyers

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CONTRIBUTION

- Propose a parsimonious theoretical framework that captures the essence of all three explanations: price-liquidity-run
- Theoretical implications: characterization, comparative statics...
- Model is numerically solved and calibrated via SMM
- Counterfactual experiments

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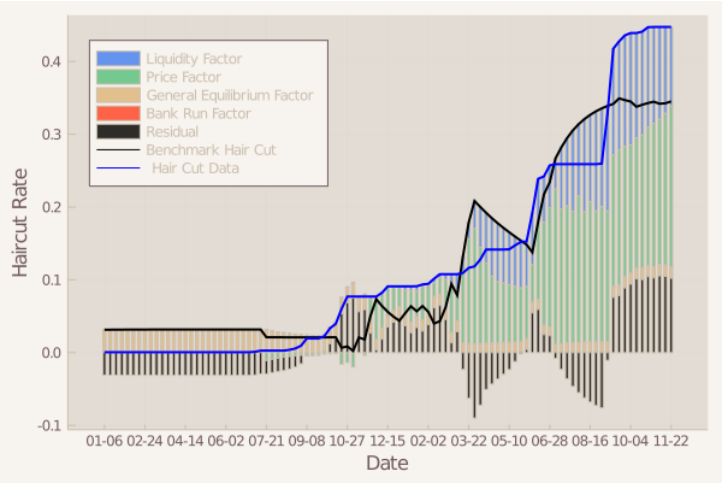
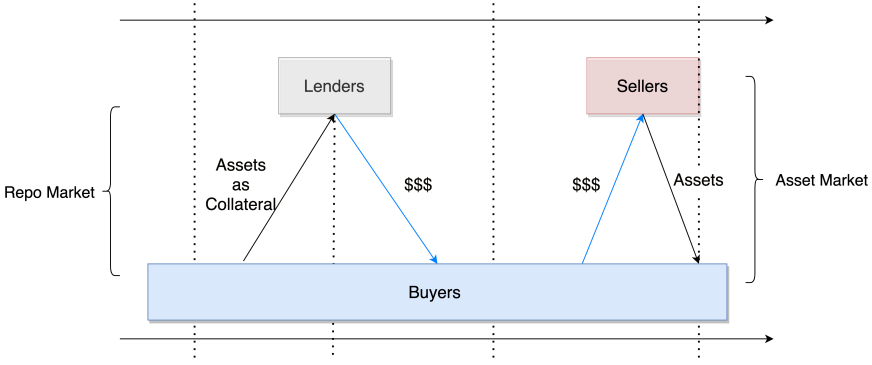
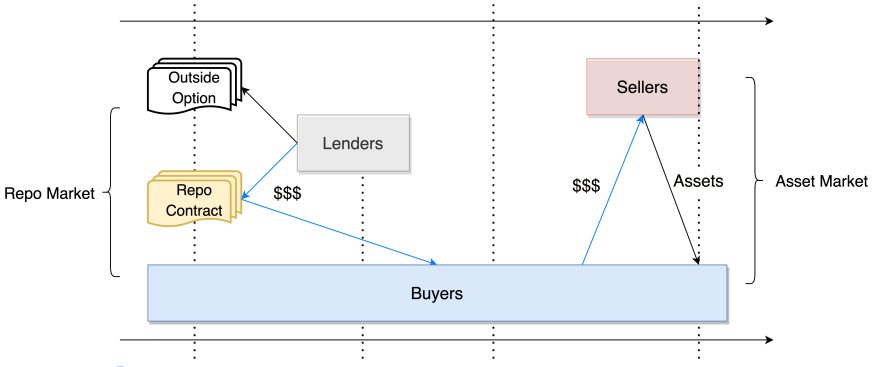


Model

OVERVIEW


Lenders
Sellers
Repo Market
Assets
as
Collateral
$$$
$$$
Assets
Asset Market
Buyers

OVERVIEW


Outside Option
Lenders
Sellers
Repo Market
Repo Contract
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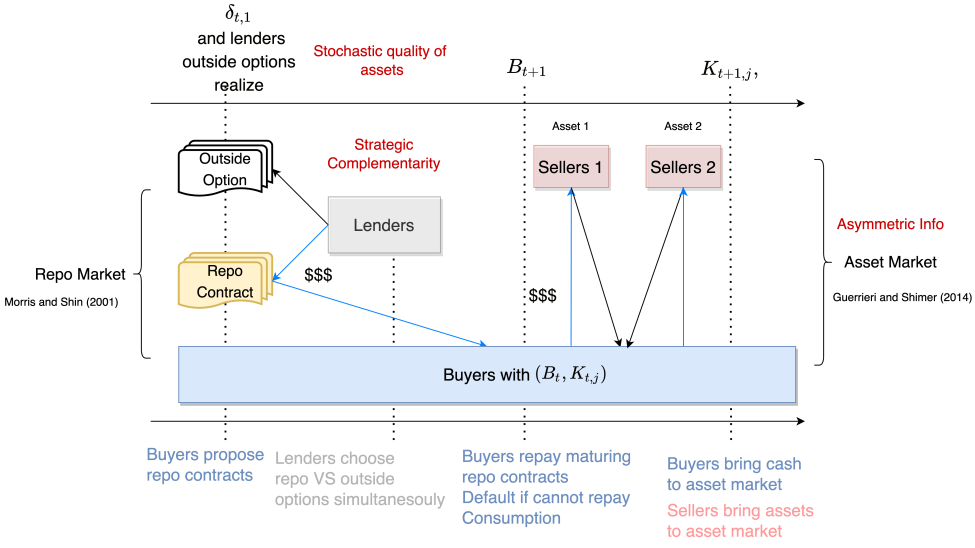
Assets
Asset Market
Buyers
Buyers propose repo contracts
Lenders choose repo VS outside options simultanesouly
Buyers repay maturing repo contracts
Default if cannot repay
Consumption
Buyers bring cash to asset market
Sellers bring assets to asset market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B_{t+1}
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Asset 1
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Morris and Shin (2001)
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ASSETS

- Assets are indivisible and generates different dividends $\delta_{t,j}$ (quality) in each period
- $j \in \{1, 2, ..., J\}$ with $J < \infty$
- Maturity of assets arrives with probability α i.i.d in each period
- Dividends $\delta_{t,1}$ follows a Markov process on a finite support
- $0 < \underline{\delta}_1 \leqslant \delta_{t,1} \leqslant \bar{\delta}_1 < \delta_2, ..., < \delta_J$
- Only source of aggregate uncertainty in the model

Back

SELLERS

- Discount factor ρ^l with linear utility
- Type j seller holds one unit of asset with quality j
- Asset quality is only observable to its seller
- Type j seller has measure M_j : fixed over time
  - Sellers will be replaced by identical clones in the next period after successfully selling the asset or the asset reaches the maturity

Back

BUYERS

- Linear utility with discount factor ρ^h
- A unit measure of buyer families and measure one of individual buyers within each family
- Individual buyers share their asset holdings and repo obligations within the family at the end of each period: eliminates the ex post heterogeneity of balance sheets
- Individual buyers issue repo on repo market and buy assets on asset market
- Individual buyers consume a constant share of dividends generated from the assets that they have purchased in previous periods
- The optimization problem is degenerated to two sub-problems: max the borrowing on repo market and max the return on asset market

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Details Back

DETAILED BUYER OPTIMIZATION

- Buyers will maximize the amount of asset purchase on asset market
- Constraint for asset purchase depend on both the repo borrowing and the balance sheet condition
- Buyers will maximize the amount of repo borrowing on the repo market
- Constraints for repo borrowing only depend on the aggregate state s_t
- Return for investment on asset market only depend on the aggregate state s_t
- Unless the target is the consumption distribution of buyers, the future aggregate state s_{t+1}, and optimal decisions for buyers on both the asset market and the repo market only depend on s_t

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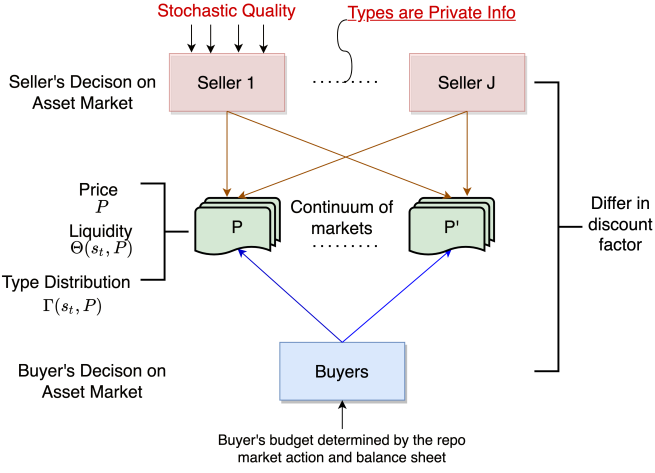
ASSET MARKET STRUCTURE

- Gains from trade generated from the gap in discount factor
- Directed search framework à la Guerrieri and Shimer (2014)
- A continuum of markets indexed by $p \in R_+$
- Each buyer and seller can take her cash/asset to any market
- Rational expectation about the tightness (buyer-seller ratio) in all markets denoted by $\Theta(s_t, p)$
- Rational expectation about types of assets sold in each market denoted by $\Gamma(s_t, p) \equiv \{\gamma_j(s_t, p)\}_{j=1}^{J} \in \triangle^J$

ASSET MARKET STRUCTURE



SELLER'S DECISION

- $s_t = (\delta_{t,1}, B_t, \{K_{t,j}\})$
- Given the market tightness function $\Theta(s_t, \cdot)$ and the transition probability of aggregate states s_t

$$\frac{1}{1-\alpha} v_j^s(s_t) = \delta_{t,j} + \max_{p \in \mathbb{R}_+} \Big\{ \min\{\Theta(s_t, p), 1\} p + \rho^l (1 - \min\{\Theta(s_t, p), 1\}) \mathbb{E}_t \left[v_j^s(s_{t+1}) \right] \Big\}.$$

BUYER'S VALUATION ON ASSET

- Let $v_j^b(s_t)$ be the value of holding one unit of type j asset
- Given the transition probability of aggregate states s_t and the expected default rate $\pi(s_t)$

$$v_j^b(s_t) = (1-\alpha)\left\{\delta_{t,j} + \rho^h(1-\pi(s_t))\mathbb{E}_t[v_j^b(s_{t+1})]\right\}$$

BUYER'S DECISION ON ASSET MARKET

- Given $\Theta(s_t, p)$ and aggregate transition of s_t
- Let $F(s_t, p)$ denote the cash spent in sub-market p when the state is s_t
- Buyers' marginal/average investment return $\lambda(s_t)$ is given by

$$\lambda(s_t) = \max_{F(s_t,p)} \left[\int_{\mathbb{R}_+} \sum_j \frac{\min\{\Theta^{-1}(s_t, p), 1\}\mathbb{E}_t[v_j^b(s_{t+1})]}{p} \gamma_j(s_t, p) dF(s_t, p) \right]$$

Back

REPO CONTRACTS

- Each repo contract has face value \$1
- Matures with Prob $\beta > \alpha$: repay when reaches maturity
- Characterized by: coupon rates R and collateral portfolio $\left(k_j(s_t)\right)_j$
- Liquidation value of collateral portfolio: market sale and fire sale
- Fire sale price is the holding value of agents who values the asset least in the model: sellers
- Prob of fire sale event is determined by the market liquidity

Back

BUYERS ON REPO MARKET

- Given the rational expectation of lender's decision
- Buyers propose take it or leave it repo contract to lenders
- Collateral promise $\leqslant$ Available asset holding
- Liquidation value of collateral $\geqslant$ \$1

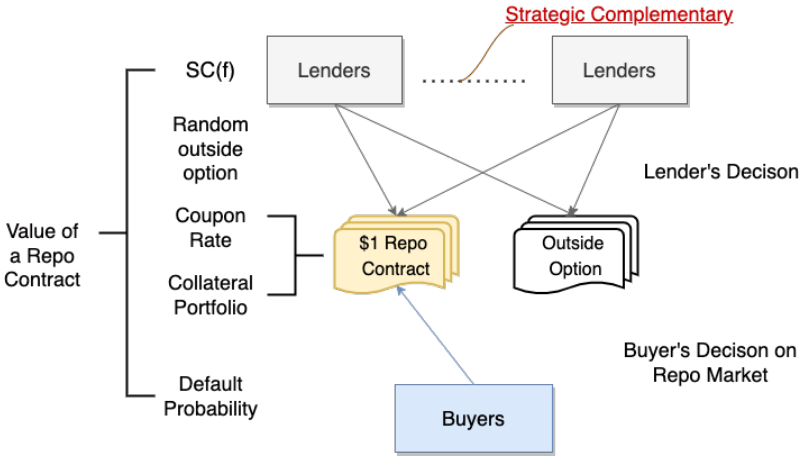
Back Buyer Decision on repo

LENDERS

- A constant measure $\bar{B}$ of lenders born each period
- Take the proposed repo contract as given and endowed with \$1
- Other lenders in utility: a linearly added term $\varphi \cdot SC(f)$
- Random outside option which contains a private idiosyncratic component and an aggregate component
- All lenders choosing between outside option and the repo contract simultaneously
- Exit the model forever after being repaid/ taking over the collaterals / choosing the outside option

Back Lender Decision

REPO MARKET STRUCTURE



LENDER'S DECISION

- For a lender associated with repo rate R and suppose that a fraction f of lenders choose the repo contract
- The difference of expected return between choosing repo contract and the outside option is

$$V^l\left(s_t, R, (k_j)_j, f, u_{i,t}\right) = \frac{R + u_{i,t}}{1 - \rho^h(1-\beta)} + \varphi \cdot SC(f) + \rho^h\Big\{ \sum_j \mathbb{E}_t\left[v_j^l(s_{t+1})\right]k_j + \mathbb{E}_t\left[v_\pi^l(s_{t+1})\right]\Big\}.$$

- This defines a simultaneous-move game $\mathcal{G}(s_t, R, (k_j)_j)$

Back

BUYER'S DECISION ON REPO MARKET

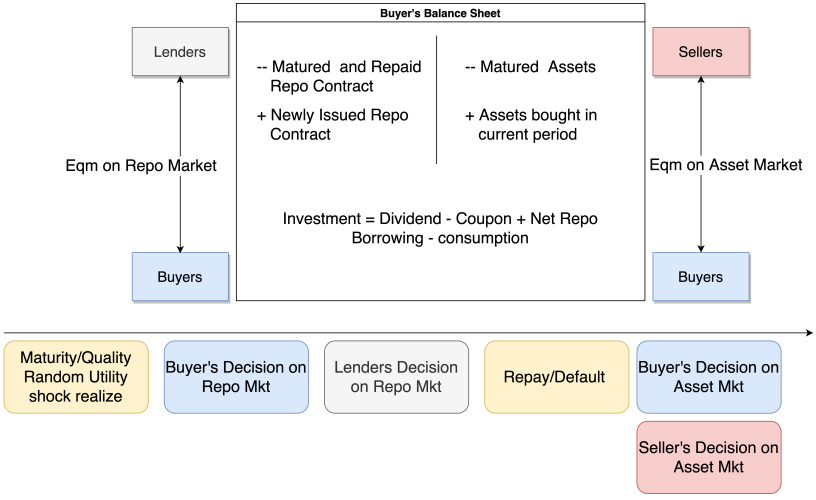
- Taking $f^*(s_t, R, (k_j)_j)$, the equilibrium of $\mathcal{G}(s_t, R, (k_j)_j)$, as given, buyer's objective is to maximize the amount of repo borrowing given the constraint of their available asset holdings

$$\max_{R,(k_j)_j} \left(1 - \frac{R}{1 - \rho^h(1-\beta)}\right) \cdot f^*(s_t, R, (k_j)_j)$$

- Subjects to the constraint on available asset holdings
- Liquidation value of $(k_j)_j$ is larger than 1

Back

TIMELINE REVISIT



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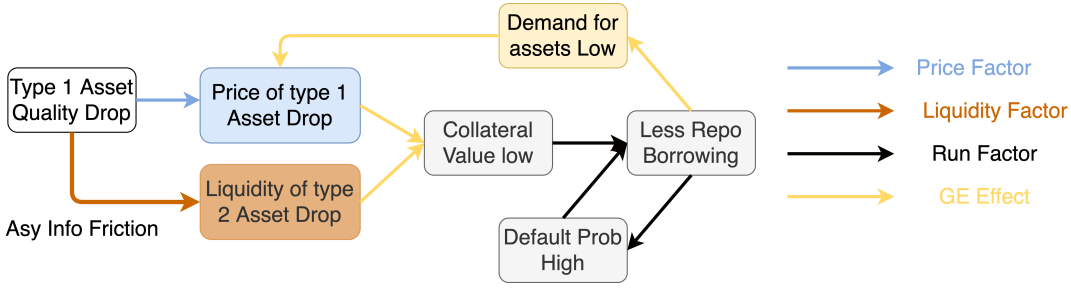

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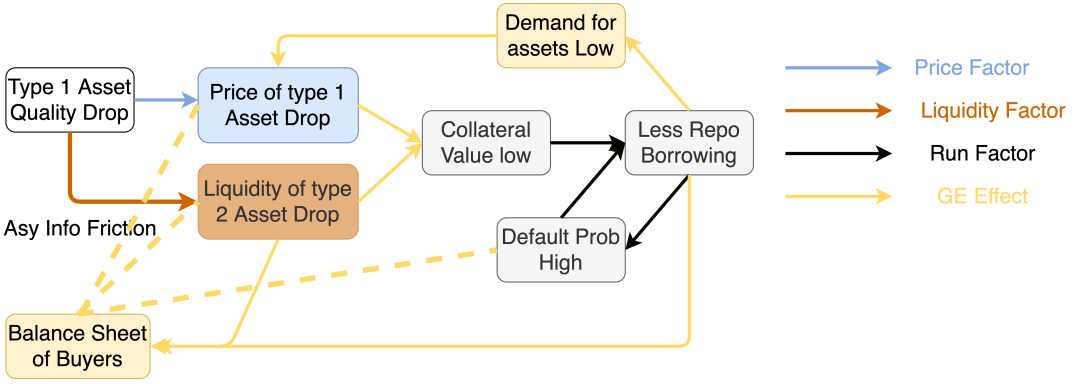

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Equilibrium

EQUILIBRIUM CONCEPT AND CHARACTERIZATION

- Equilibrium on asset market is similar with Guerrieri and Shimer (2014)
  - Key outside eqm path belief restriction that is close to intuitive criterion
  - Complete separating, higher types are sold with higher prices but lower liquidities
- On the repo market: lenders' policies constitute an IDDS similar with Morris and Shin (2001)
  - Threshold eqm for lenders
- Markov Perfect Equilibrium
  - $J+2$-dimensional pay-off relevant state $(\delta_{t,1}, B_t, K_{t,1}, ..., K_{t,J})$
  - Buyers optimize
  - Evolution of B_t follows from the eqm on the repo market
  - Evolution of $K_{t,1}, ..., K_{t,J}$ follows from the eqm on the asset market

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Calibration

FUNCTIONAL FORMS

- Default Prob

$$\pi(Cash) = \epsilon + I_{Cash>0}\left[1 - \exp\left(-\eta \cdot Cash^{-}\right)\right] - I_{Cash<0}\left[1 - \exp\left(-\eta \cdot Cash^{+}\right)\right]$$

- Fire Sale Prob

$$Pr(\theta) = 1 - \frac{\nu_3}{\left(1 + \nu_4 \cdot \exp\left(-\nu_2(\theta - \nu_1)\right)\right)^{1/\nu_4}}$$

- Strategic Complementarity

$$\varphi \cdot \left\{ \ln\left(\frac{f}{\bar{f}}\right) \cdot I_{f \geqslant \underline{f}} + I_{f<\underline{f}} \cdot \left\{ \frac{\bar{f}}{\underline{f}} \cdot f + \ln\left(\underline{f}/\bar{f}\right) - \bar{f} \right\} \right\}$$

PARAMETERS

- Parameters that can be directly assigned: $\rho^h, \alpha, \beta, \bar{B}, J, \delta_{t,2}$
- Quality of Assets: $\delta_{t,1}$ process
- Asset Market Parameters: $M_1, ..., M_J$
- Repo Market Parameters
  - Liquidation value of collaterals: $\rho^l, \nu_1, ..., \nu_4$
  - Repo contracts: $\varphi, \sigma, \sigma_0, \eta, \epsilon$

TARGETS

- Price explanation: map $\delta_{t,1}$ process with ABX index ABX
- Liquidity explanation: map $M_1, ..., M_J$ with loss distribution of a universal sample of RMBS from Ospina and Uhlig (2018) Asset Distribution
- Run explanation: map other repo market parameters with joint dynamics of hair cut path, LIB-OIS rate and Repo spread reported in Gorton (2012)
  Repo Market Calibration

ABX

- ABX.HE AAA 07-01
- δ_2 normalized to 1
- Key difficulty: downward trend for ABX between 2007-2009
- Assuming ABX index is a martingale
- Under the above constraint, we estimate the $\delta_{t,1}$ process with the observed path from 2007 to 2009

back

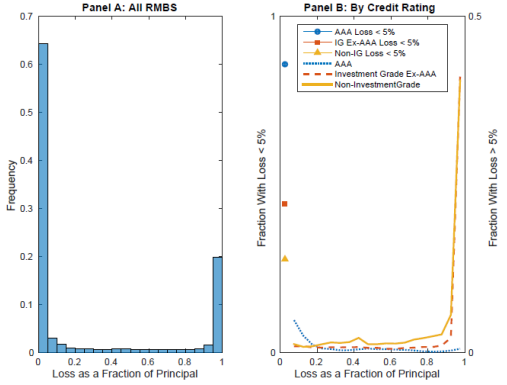
ASSET MARKET PARAMETERS

- Exhaust the pre-crisis information: assuming assets are traded with highest possible prices and liquidities before 2006
- $M_1, ..., M_J$ are one-to-one mappings to the observed quality distribution

back

ASSET MARKET PARAMETERS

Figure 2: Distribution of Loss Size for All RMBS



Panel A presents the distribution of cumulative losses as of December 2013 as a fraction of the original principal amount for all the RMBS in our database issued from 1987 through 2008. Panel B shows the distribution of cumulative losses as of December 2013 as a fraction of the original principal amount for different groups of RMBS based on the type of the underlying mortgage loans.

REPO MARKET PARAMETERS

- η and ϵ are calibrated by observed LIB - OIS spread path
- $\nu_1, ..., \nu_4$ and ρ^l are jointly calibrated in the equilibrium to match the hair cut rate path
- The equilibrium framework generates the following relationship

$$R(s_t) = \rho^h \mathbb{E}_t \left\{ \sum_j v_j^l(s_{t+1}) k_j + v_\pi^l(s_{t+1}) \right\} + \varphi \mathbb{E}_t \left[\ln \left(\frac{f(s_t)}{\bar{f}} \right) \right] - \sigma \Phi^{-1}(1 - f(s_t))$$

- Assuming σ_0 satisfies our condition for the repo market equilibrium uniqueness
- By targeting first order moments of $R(s_t)$ in first and second half of 2007 and the whole year of 2008, I obtain σ_0, σ and φ

back

Simulation

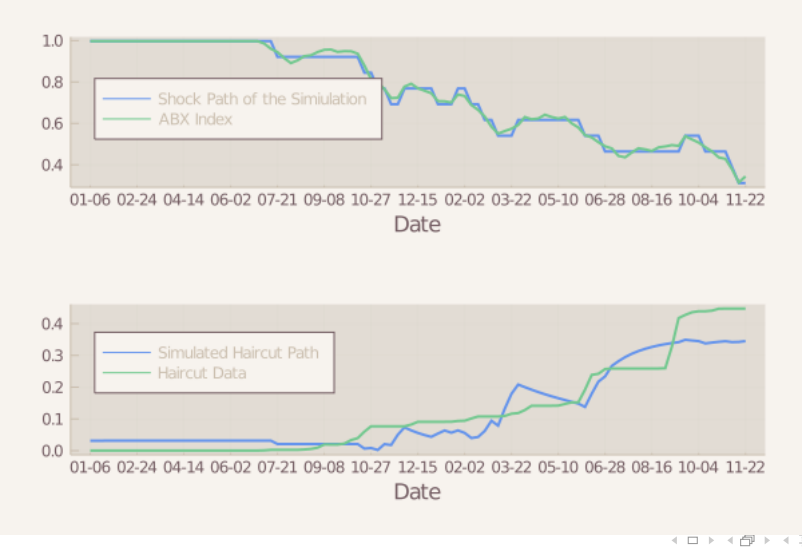
SIMULATION

- Initial state: not the determinant steady state
- Start from any state, feed in 1000 times the $\bar{\delta}_1$
- From period 1001, feed in the approximated ABX shocks

SMM ESTIMATION

	Targets			**Simulation**		
	Pre crisis	Second half of 2007	2008	Pre crisis	Second half of 2007	2008
Repo Rate	6.41bp	76.35bp	199.44bp	16.62bp	45.69bp	205.63bp
LIB - OIS	7.97bp	58.71bp	108.1bp	0bp	50.91bp	111.65bp

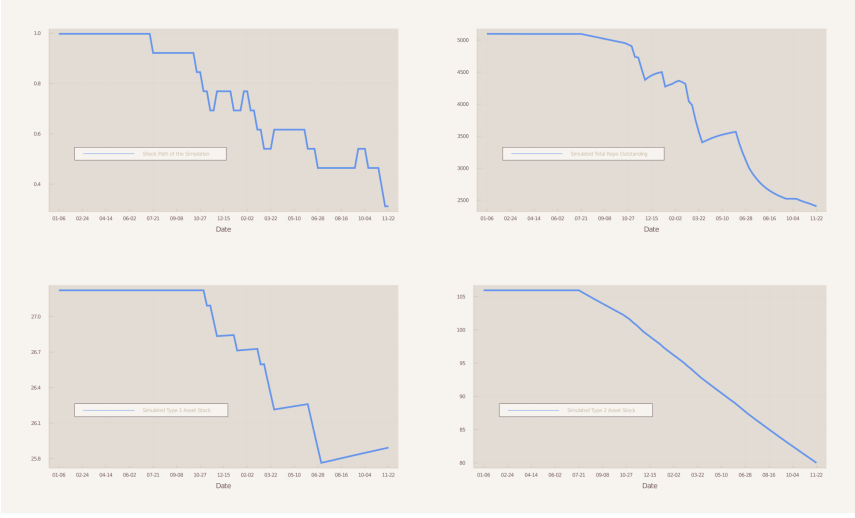
SIMULATED PATH VS TARGETS



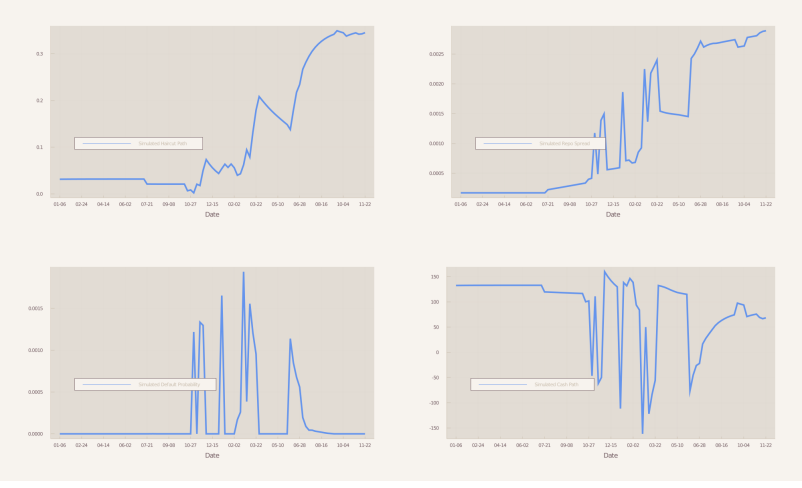
SMM ESTIMATION: UNTARGETED MOMENTS

- Total repo liabilities of broker-dealers drop 40%
- The relative (to pre-crisis 2006 level) total issuance of RMBS in 2007 and 2008 are 75.8% and 8.4%, my model produces 70.1% and 12.5%
- The average transaction price of RMBS by insurance companies reported in Merrill et al. (2013) is very similar to my simulated path

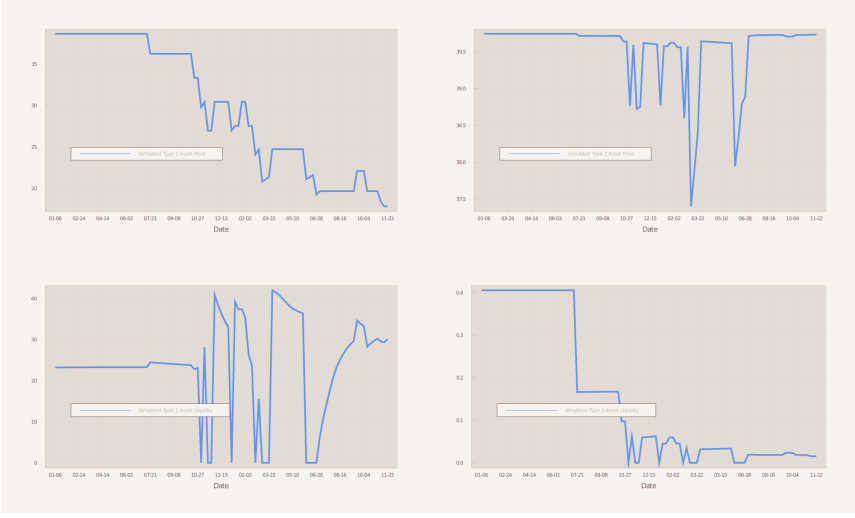
SIMULATED PATH: BALANCE SHEET



SIMULATED PATH: REPO MARKET



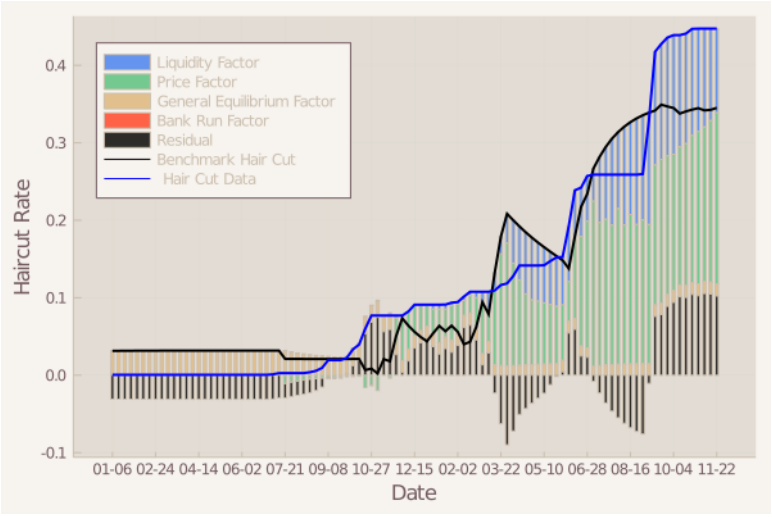
SIMULATED PATH: ASSET MARKET



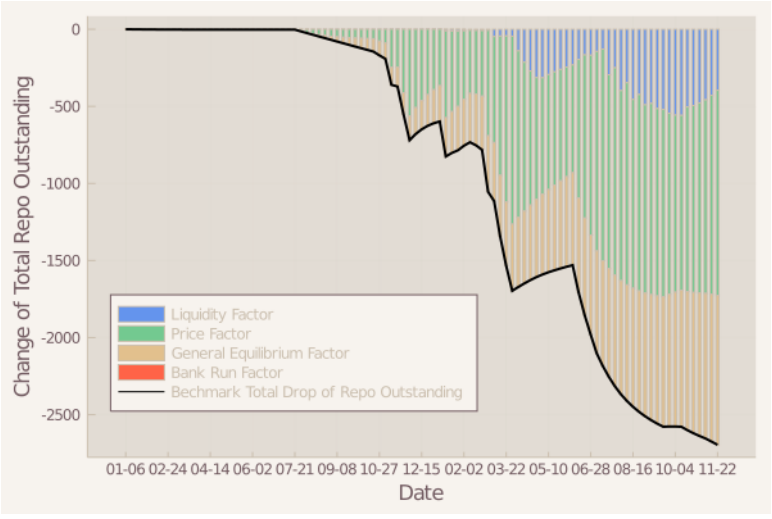
COUNTER-FACTUAL EXPERIMENTS

- Liquidity explanation: Shutting the asymmetric information down and resolve the equilibrium.
  - Maintain the directed search structure on asset market: different types of assets have different prices but the same liquidity which is determined by the aggregate demand VS supply
  - To be consistent with out initial state assumption and to focus on the liability side, I use the asset path generated from benchmark simulation
- Run explanation: Assuming $\varphi = 0$
- Combining the above two experiments together: price explanation + GE effect left
- Shutting down the shock

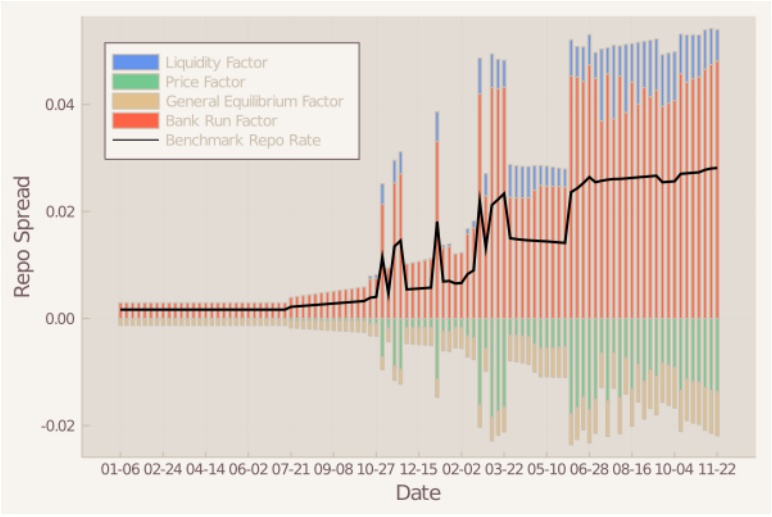
DECOMPOSITION: HAIR CUT RATE



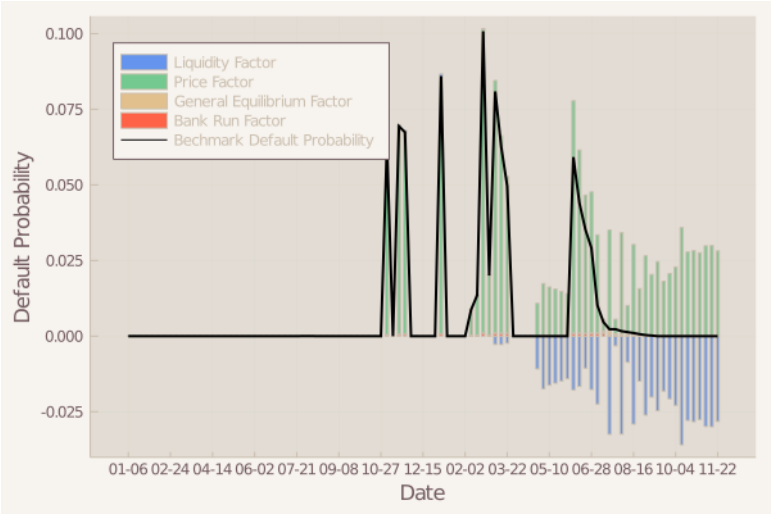
DECOMPOSITION:REPO OUTSTANDING



DECOMPOSITION:REPO RATE



DECOMPOSITION:DEFAULT PROB



RESULTS TAKEAWAY

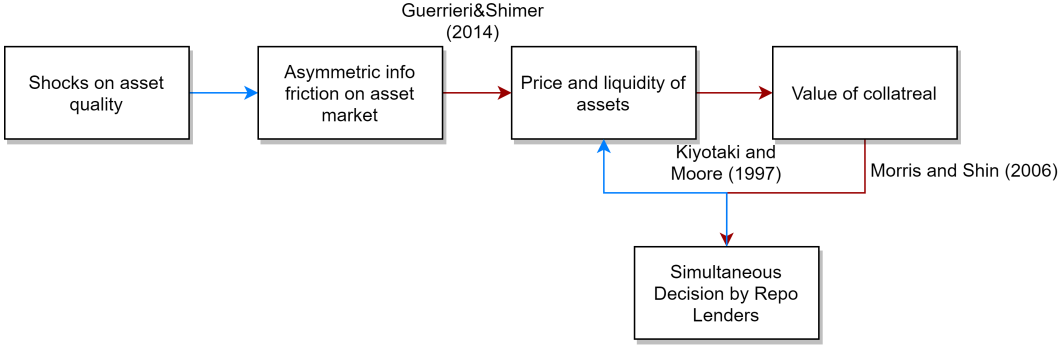
- Liquidity explains 30% of the increase in haircut, 13% of the drop in total repo outstanding, and a large part of the increase in repo spread
- The fundamental-based run has a significant and persistent effect on the repo spread but only a small effect on the repo haircut
- The GE effect explains 33% of the drop in total repo outstanding

Extensive Margin VS Intensive Margin Panic Based Run Policy Intervention

POLICY IMPLICATIONS

- Bailing out banks in trouble may not be as costly as previously believed
- Effectiveness of the unconventional monetary policies: liquidity programs
- Ineffectiveness of the conventional monetary policies: Fed fund rate cut
  - The ineffectiveness is independent of the zero lower bound
- The regulation authority need an integrated view on the asset market and the repo market
- Additional theoretical result on the macro-prudential policies: compulsory cash reserve

LITERATURE


Guerrieri&Shimer (2014)
Shocks on asset quality
Asymmetric info friction on asset market
Price and liquidity of assets
Value of collatreal
Kiyotaki and Moore (1997)
Morris and Shin (2006)
Simultaneous Decision by Repo Lenders

THANK YOU

EXTENSIVE MARGIN VS INTENSIVE MARGIN

$$\max_{R,(k_j)_j} \left(1 - \frac{R}{1-\rho^h(1-\beta)}\right) \cdot f^*(s_t, R, (k_j)_j)$$
$$C(s_t, (k_j)_j) \geqslant 1$$
$$k_j \leqslant \frac{K_{t,j}}{f^*(s_t, R, (k_j)_j) \cdot \bar{B}}$$

The calibration suggests the buyer always want to issue the largest possible amount of repo contract, but is limited by the constraint $C \geqslant 1$ during the crisis

PANIC-BASED RUN?

- Chapter 11 bankruptcy on Sep by Lehman Brothers
- Side evidence: Average mortgage collateral default rate doesn't jump much after the Sep of 2009, reported by Merrill et.al (2013)
- Parameter Restriction: the condition for uniqueness of equilibrium on repo market is binding for estimated parameters

ROBUSTNESS OF THE CALIBRATION STRATEGY

- Focus on the policies implemented between 2007-2009
- Fed funds rate cuts
  - One-time jump of repo spread
  - My result will not be greatly impacted since I target the average repo spread
- liquidity programs to keep the financial institution operating
  - TALF, TSLF, PDCF are directly related with the asset considered in my model (private-labeled RMBS)
  - TALF commenced operation in March 2009
  - TSLF is similar with PDCF: push up η
- guarantee programs to support the critical funding markets for financial institutions
  - Maiden Lane for Bear Stern
  - An example of how η in my model works

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