The Collateral Link Between Volatility and Risk Sharing

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Financial Stability in Times of Macroeconomic Uncertainty
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[1] The views of this presentation are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or of any other person associated with the Federal Reserve System.

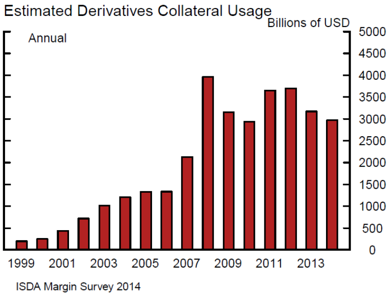
Motivation

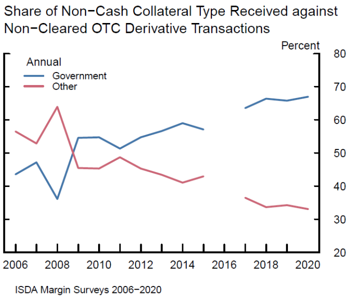
- **How does future aggregate risk affect current financial stability?**

Collateral and Risk Sharing

- Financial stability relies on interbank markets to share idiosyncratic risks.
  - Intensive trading of derivative and repo contracts to hedge against shocks.
  - Given counterparty risk, credit enhancement through collateral.

    "The use of collateral agreements is substantial. Among all firms responding to the survey, 91% of all OTC derivatives trades (cleared and non-cleared) were subject to a collateral agreements at the end of 2013." ISDA 2014 .
  - The volume and composition of collateral has changed dramatically in recent years.





Collateral and Stores of Value

- But the same assets are used for many purposes
  - **Collateral:** intra-temporally smoothing: Reduces exposure to idiosyncratic risk.
  - **Stores of Value:** inter-temporally smoothing: Exposure to aggregate risk?

    It depends....public or private

- ...and these uses are intimately related through valuation effects
  - Assets' use as collateral affects their value as store of value

    $\longrightarrow$ **convenience yield**
  - Assets' use as store of value affects their value as collateral

    $\longrightarrow$ **stochastic discount**

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Preview of Main Results

- Punchline
  - Increase in aggregate volatility increases (decreases) the price of public (private) assets, increasing (decreasing) risk sharing.
  - When aggregate volatility increases, financial markets are less stable when interbank markets rely heavily on private collateral.
- Testable prediction & empirical evidence:
  - Sensitivity of risk sharing to volatility depends on share of private/public collateral
  - We test this prediction exploiting that, since the 1950's, the US increasingly relied on private collateral, reverting the trend after 2008.

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Related Literature

- Private and Public Assets:
  - Holmstrom & Tirole (1998), Krishnamurthy (2003), Sunderam (2014), Krishnamurhty & Vissing-Jorgensen (2015), Greenwood, Hansen, & Stein (2015), Nagel (2016), Gorton (2017), Infante (2020), Gorton & Ordoñez (2020)
- Asset valuations and risk-sharing:
  - Mankiw (1986), Constantinides & Duffie (1996), Storesletten, Telmer, & Yaron (2007), Hurst & Stafford (2004), Lustig & van Nieuwerburgh (2010)
- Valuation and sensitivity of US Treasuries
  - , Caballero, Farhi, & Gourinchas (2017), He, Krishnamurthy, & Milbradt (2019), Jiang et al. (2019), Reis (2021)

Model

Simple Setting with Aggregate and Idiosyncratic Shocks

- Three periods: $t \in \{0, 1, 2\}$
- Two agents: Raymond (R) and Shirley (S). (standard preferences $u(c_t)$)
  - They have identical aggregate endowment process: $\frac{\tilde{Y}_t}{2} \sim G(\cdot)$.
  - They suffer idiosyncratic shock $\tilde{y}$ in $t = 1$ (2 states, same probability):
    - Raymond gets $\overline{y}$ if it rains (r), $-\overline{y}$ if it shines (s)
    - Shirley gets $-\overline{y}$ if it rains (r), $\overline{y}$ if it shines (s)
- Three assets:
  - Short-term public bonds: payoff of 1 in $t = 1$ (taxation), total supply Θ_0^{Sh}, price p_t^{Sh}
  - Long-term public bonds: payoff of 1 in $t = 2$ (taxation), total supply Θ_0, price p_t
  - Private asset: payoff of $\tilde{a}_t = \rho \tilde{Y}_t$ with $\rho \in (0, 1)$, total supply $\hat{\Theta}_0$, price p_t^a
- In each t, after shocks are realized, agents rebalance portfolios: $\theta_{ti}^{Sh}, \theta_{ti}$ and $\hat{\theta}_{ti}$

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State Contingent Contracts and Financial Frictions

- In $t = 0$ agents want to share idiosyncratic risks, and they can trade promises: w_i^r (if rainy) or w_i^s (if sunny) at prices q^r and q^s respectively....

- ...but they do not trust the counterparty – **financial friction!!!!**

- Promises need to be *fully collateralized*—protected by worst case outcome:

$$w_i^r, w_i^s \leq \theta_{0i}^{Sh} + \underline{p}_1 \theta_{0i} + \alpha \underline{p}_1^a \hat{\theta}_{0i}$$

  for $i \in \{R, S\}$, where $\underline{p}_1$ and $\underline{p}_1^a$ are the lowest prices at $t = 1$.

- Exogenous parameter $\alpha \in (0, 1)$ is the *collateralizability of the private asset*

- Public and private assets can be used both as collateral and stores of value!

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Pricing in the Symmetric Equilibrium

- In $t = 0$ agents choose portfolio and insurance (possible rebalancing at $t = 1$).
  Raymond sells insurance for when it rains and buy insurance for when it shines

- In equilibrium, the price of short-term government bond, for instance, is:

$$p_0^{Sh} = \underbrace{\beta \mathbb{E}_0 \left(\frac{u'(\tilde{c}_{1R})}{u'(c_0)} \right)}_{\text{Value as Storage}} + \underbrace{\left[\frac{\beta}{2} \mathbb{E}_0 \left(\frac{u'(\tilde{c}^s_{1R}) - u'(\tilde{c}^r_{1R})}{u'(c_0)} \right) \right]}_{\text{Value as Collateral}}$$

- Difference between $\tilde{c}^s_{1R}$ and $\tilde{c}^r_{1R}$ captures the convenience yield
  - The extent of idiosyncratic risk – Insurance Demand.
  - The degree of idiosyncratic hedge – Insurance Supply.

- Note that, if $\tilde{c}^s_{1R} = \tilde{c}^r_{1R}$ (full risk sharing) there is no convenience yield

Optimization Problem

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- In $t = 0$ agents choose portfolio and insurance (possible rebalancing at $t = 1$).
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- In equilibrium, the price of all assets are:

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$$p_0 = \beta \mathbb{E}_0 \left(\tilde{p}_1 \frac{u'(\tilde{c}_{1R})}{u'(c_0)} \right) + \underline{p}_1 \left[\frac{\beta}{2} \mathbb{E}_0 \left(\frac{u'(\tilde{c}_{1R}^s) - u'(\tilde{c}_{1R}^r)}{u'(c_0)} \right) \right]$$

$$p_0^a = \beta \mathbb{E}_0 \left((\tilde{a}_1 + \tilde{p}_1^a) \frac{u'(\tilde{c}_{1R})}{u'(c_0)} \right) + \alpha \underline{p}_1^a \left[\frac{\beta}{2} \mathbb{E}_0 \left(\frac{u'(\tilde{c}_{1R}^s) - u'(\tilde{c}_{1R}^r)}{u'(c_0)} \right) \right]$$

Optimization Problem

Special Case: CARA Utility, $\tilde{Y}_1 = Y_1 = 0$, and $\tilde{Y}_2 \sim N(\mu, \sigma^2)$

- Simplifying assumptions imply:
  - No wealth effects
  - $t = 1$ prices are deterministic: $\tilde{p}_1 = \underline{p}_1 = p_1$ and $\tilde{p}_1^a = \underline{p}_1^a = p_1^a$
  - $t = 1$ prices are independent of idiosyncratic shocks (water under the bridge)

- If $\overline{y}$ is large, $t = 0$ insurance contracts are at a corner

$$\overline{y} > w := w_R^r = w_S^s = \frac{\Theta^{Sh}}{2} + p_1 \frac{\Theta_0}{2} + \alpha p_1^a \frac{\hat{\Theta}_0}{2}$$

- At $t = 1$, agents rebalance their risk-free portfolio upon the idiosyncratic shock.
  - if it rains, Raymond buys more of the long-term asset

$$(\overline{y} - w) - p_1 \left(\theta_{1R}^r - \frac{\Theta}{2} \right) = \left(\theta_{1R}^r - \frac{\Theta}{2} \right)$$

- Hence, optimal consumption in $t = 1$ whether it rains or shines is

$$c_{1R}^r = \frac{(\overline{y} - w)}{(1 + p_1)}, \quad c_{1R}^s = -\frac{(\overline{y} - w)}{(1 + p_1)}$$

- c_{1R}^s captures the degree of idiosyncratic insurance.....$c_{1R}^s = 0$ is full insurance

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▸ Pricing in $t = 1$ ▸ Theorem

Pricing Comparative Statics as Expected

- The $t = 0$ price of long-term public assets decline when there is:
  - More public assets, Θ_0^{Sh}, Θ_0.
  - More private asset pledgeability, α.
  - Less idiosyncratic shocks, $\overline{y}$.

- Results driven by better idiosyncratic insurance, captured by higher c_{1R}^s.

Main Result: Comparative Statics on σ^2

- Interesting case: The price of private assets in $t = 1$ decreases with σ^2 (Assumption A4)
- Changes in idiosyncratic insurance:

$$\frac{\partial c^s_{1R}}{\partial \sigma^2} = \frac{1}{(1+p_1)} \underbrace{\left[\overbrace{\frac{\partial p_1}{\partial \sigma^2}}^{>0} \left(\frac{\Theta_0}{2} + \frac{(\overline{y} - w)}{(1+p_1)} \right) + \alpha \overbrace{\frac{\partial p^a_1}{\partial \sigma^2}}^{<0} \frac{\hat{\Theta}_0}{2} \right]}_{\text{valuation effect}}$$

- If the economy relies more on private collateral, idiosyncratic insurance declines with future volatility!

If $\alpha p^a_1 \hat{\Theta}_0 > p_1 \Theta_0$ then $\frac{\partial c^s_{1R}}{\partial \sigma^2} < 0$

- **Main empirical prediction:** if $\alpha p^a_1 \hat{\Theta}_0 > p_1 \Theta_0$

$$\frac{\partial CY}{\partial \sigma^2} = -\gamma p^{Sh}_0 \frac{\partial c^s_{1R}}{\partial \sigma^2} > 0$$

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Model Extension: Private Asset Creation

- Raymond and Shirley can now create private assets at a cost C, with $C', C'' > 0$
- Equilibrium in CARA-Normal specification:

$$C'(x^*) = p_0^a$$

- How does private asset creation change with σ^2?

  If α is low, the CY effect on private valuation is small

  $\implies \frac{\partial p_0^a}{\partial \sigma^2} < 0$, stable economies induce private asset creation, sowing the seeds for future instability in case of sudden increases in aggregate uncertainty!

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Empirical Results

Testable Prediction & Empirical Strategy

- **Testable Prediction:**
  The more private collateral is used, risk-sharing declines more strongly in response to increases in aggregate volatility.
  i.e.,The more private collateral is used, CY increases more with VIX.

- **Empirical strategy:**
  à la Nagel (2016), in time frames with different intensity of private collateral:

$$\Delta CY_t = \beta_0 + \beta_V \Delta VIX_t + \sum \gamma_j \Delta CY_{t-j} + \beta_{DF} \Delta FedFunds_t + \beta_F FedFunds_{t-1} + \beta_\theta \Delta Gov_t + \epsilon_t$$

β_V is positive and larger when more private assets are used

▸ Yields and Volatility

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Yields and Volatility

Long-term Analysis

- Gorton, Lewellen and Metrick (2012) show a steady increase in the share of private "safe assets" (heavily used as collateral) since 1950.
- Data and Frequency:
  - Sample from 1950–2011 split in 1990.
  - Monthly frequency, CY_t: Bankers Acceptance Note minus 3-month T-bill (Nagel 2016).

	Pre-1990	Post-1990	Pre-1990	Post-1990
$\Delta FedFunds_t$	0.197***	0.107***	0.196***	0.082**
	(0.030)	(0.036)	(0.030)	(0.034)
$FedFunds_{t-1}$	0.003	0.001	0.004	0.000
	(0.002)	(0.002)	(0.002)	(0.002)
ΔVIX_t	0.005	0.007***	0.005	0.008***
	(0.003)	(0.002)	(0.003)	(0.003)
$\Delta log(TBillsOut_t / GDP_t)$			-0.267*	-0.409**
			(0.150)	(0.166)
$\Delta log(USTNotesOut_t / GDP_t)$			-1.200	-0.324
			(0.801)	(0.278)
P-value	0.815	0.100	0.775	0.138
Adj RSq	0.199	0.110	0.207	0.132
N obs	476	264	476	264

Alternative Explanation

- We propose a **collateral supply** (via valuation) link of volatility and risk sharing...
  ...but, maybe **collateral demand** changed,

- **Empirical Strategy:** Use high frequency data, and changes in short-term T-bills as an instrument to isolate how volatility affects the demand for safety.

▸ Instrument Safe Asset Demand

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Shot-term Analysis

- Regulatory changes after 2008 changed the reliance on private assets

  $\longrightarrow$ E.g., LCR disincentives use of private assets to back financial claims
- Data and Frequency:
  - Sample from 2004–2020 split in 2009.
  - Daily frequency, CY_t: 1-month OIS minus 4 week T-bill (5-day changes overlapping).

	Pre- 2009	Post- 2009	Pre- 2009	Post- 2009
$\Delta FedFunds_t$	-0.156*	-0.117***	-0.167**	-0.120***
	(0.080)	(0.030)	(0.076)	(0.030)
$FedFunds_{t-5}$	0.013**	-0.002	0.012*	-0.001
	(0.007)	(0.003)	(0.006)	(0.003)
$\Delta log(ShortTBillsOut_t)$	-0.663***	-0.098***	-0.681***	-0.099***
	(0.168)	(0.024)	(0.165)	(0.025)
$\Delta log(USTNotesOut_t)$	-1.479	0.311	-1.340	0.317
	(3.368)	(0.447)	(3.202)	(0.450)
$\Delta log(ShortTBillsOut_t) \times \Delta VIX_t$			0.012	0.006
			(0.050)	(0.007)
ΔVIX_t			0.008**	-0.001
			(0.003)	(0.001)
P-value	0.349	0.000	0.320	0.000
Adj RSq	0.107	0.106	0.125	0.107
N obs	682	1724	682	1723

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Concluding Remarks

- Interbank risk sharing depends on the mix of public and private collateral.
- A higher reliance on private collateral makes financial markets less stable.'
- Policy implication: Control the use of private collateral to make the financial system more stable when an aggregate uncertainty shock hits the economy.
- How? Managing margins for derivatives and repo collateral? New programs to exchange public for private assets or to guarantee private assets in the presence of uncertainty shocks?

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Optimal Strategy in $t = 0$

- Agent i maximizes

$$Max_{\{\theta_{0i},\theta_{0i}^{Sh},\hat{\theta}_{0i},w_i^r,w_i^s\}} u(c_{0i}) + \beta\mathbb{E}_0(U_i(\theta_{0i},\theta_{0i}^{Sh},\hat{\theta}_{0i},w_i^r,w_i^s;\tilde{Y}_1))$$

subject to

$$\begin{aligned} w_i^r &\leq \theta_{0i}^{Sh} + \underline{p}_1\theta_{0i} + \alpha\underline{p}_1^a\hat{\theta}_{0i} \\ w_i^s &\leq \theta_{0i}^{Sh} + \underline{p}_1\theta_{0i} + \alpha\underline{p}_1^a\hat{\theta}_{0i} \\ 0 &\leq \theta_{0i}^{Sh},\theta_{0i},\hat{\theta}_{0i} \end{aligned}$$

where U_i is i's optimal payoff in $t = 1$

▸ $t = 0$ Equilibrium

CARA Normal Pricing in $t = 1$ & H-J Bounds

$$
\begin{aligned}
p_1 &= \beta \exp\left\{-\frac{\gamma}{2}\left(1+\rho\hat{\Theta}_0\right)\mu + \frac{1}{8}\gamma^2\left(1+\rho\hat{\Theta}_0\right)^2\sigma^2\right\} \\
p_1^a &= \rho\left(\mu - \frac{\gamma}{2}\left(1+\rho\hat{\Theta}_0\right)\sigma^2\right)p_1
\end{aligned}
$$

Lemma

The Hansen-Jagannathan bounds for the pricing in $t = 1$ is given by

$$
\left|\left(\mu - \frac{\gamma}{2}\left(1+\rho\hat{\Theta}_0\right)\sigma^2\right)\frac{\gamma}{2}\left(1+\rho\hat{\Theta}_0\right)\right| \leq \exp\left\{\frac{1}{4}\gamma^2\left(1+\rho\hat{\Theta}_0\right)^2\sigma^2\right\} - 1.
$$

▸ CARA Normal

Equilibrium in Special Case

Theorem

If $\overline{y} \in [\frac{\Theta_0^{Sh}}{2} + \frac{\Theta_0}{2} + \alpha\frac{\hat{\Theta}_0}{2}, \frac{\Theta_0^{Sh}}{2} + \Theta_0 + \alpha\rho(\mu - \frac{\gamma}{2}(1+\rho\hat{\Theta}_0)\sigma^2)\frac{\hat{\Theta}_0}{4}]$, $\beta > \frac{1}{2}$, $\left(\mu - \frac{\gamma}{2}\left(1+\rho\hat{\Theta}_0\right)\sigma^2\right) \in (0,1)$, *the H-J bound holds, and* $\frac{\gamma}{2}\left(1+\rho\hat{\Theta}_0\right)\sigma$ *sufficiently small enough, then there exists a symmetric equilibrium with*

$$\begin{aligned} p_0^{Sh} &= p_0^{rf} + CY \\ p_0 &= p_1\left(p_0^{rf} + CY\right) \\ p_0^a &= p_1^a\left(p_0^{rf} + \alpha CY\right). \end{aligned}$$

where $p_0^{rf} := \beta\mathbb{E}_0\left(\frac{u'(\tilde{c}_{1R})}{u'(c_0)}\right)$ *the price of a risk free asset without a convenience yield.*

▸ Special Case

β of Public and Private Assets

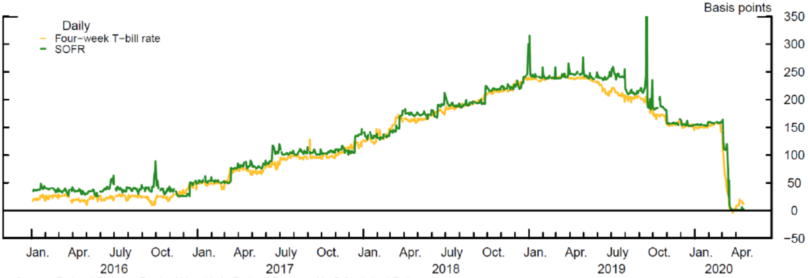
- How do public and private valuations change with volatility?
- Assumption A4 requires that private asset prices *decrease* when volatility increases

	Δ10-year UST	ΔMBS	ΔIG Corp Bonds	ΔHY Corp Bonds
$\Delta FedFunds_t$	-0.065	-0.021	-0.087*	0.005
	(0.047)	(0.056)	(0.051)	(0.071)
$FedFunds_{t-5}$	-0.002	-0.002	0.001	-0.001
	(0.002)	(0.003)	(0.002)	(0.003)
$\Delta log(ShortTBillsOut_t)$	-0.005	0.024	0.077	0.105
	(0.064)	(0.068)	(0.064)	(0.112)
$\Delta log(USTNotesOut_t)$	-1.777**	-2.242**	-3.078***	-3.353*
	(0.807)	(0.949)	(0.957)	(2.020)
ΔVIX_t	-0.012***	-0.007***	-0.002	0.038***
	(0.002)	(0.002)	(0.002)	(0.003)
P-value	0.340	0.184	0.018	0.000
Adj RSq	0.099	0.037	0.051	0.340
N obs	2406	2404	2604	2604

▸ Testable Predictions

Short-term T-bill Supply Exogeneity Shock

- Changes in short-term T-bill outstanding affect total supply of safe assets.
  $\longrightarrow$ supply shock that allows to identify demand.
- Four-week T-bill rate is lower than prevailing overnight repo rates:



Source: Federal Reserve Bank of New York, Federal Reserve H.15 Statistical Release.

- Unlikely dealers would issue liabilities to finance short term T-bill: negative carry

▸ Alternative Explanation