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Intermediary Asset Pricing

Zhiguo HE and Arvind KRISHNAMURTHY,
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Presented by: Pradeep Murthykrishna

Background

- Recent Events:
  - High spreads in debt markets – August 2007 to October 2008 (Subprime Crisis)
  - S&P 500 near all time high in August 2008
  - Similar pattern in Q4 1998 (Hedge Fund Crisis)

- Narrative: intermediaries get in trouble, drive up required risk premium in intermediated asset.

Outline

- The Model
- Calibration
- Crisis Episode
  - Crisis risk premia and flight to quality
  - Crisis recovery
- Policy Experiments

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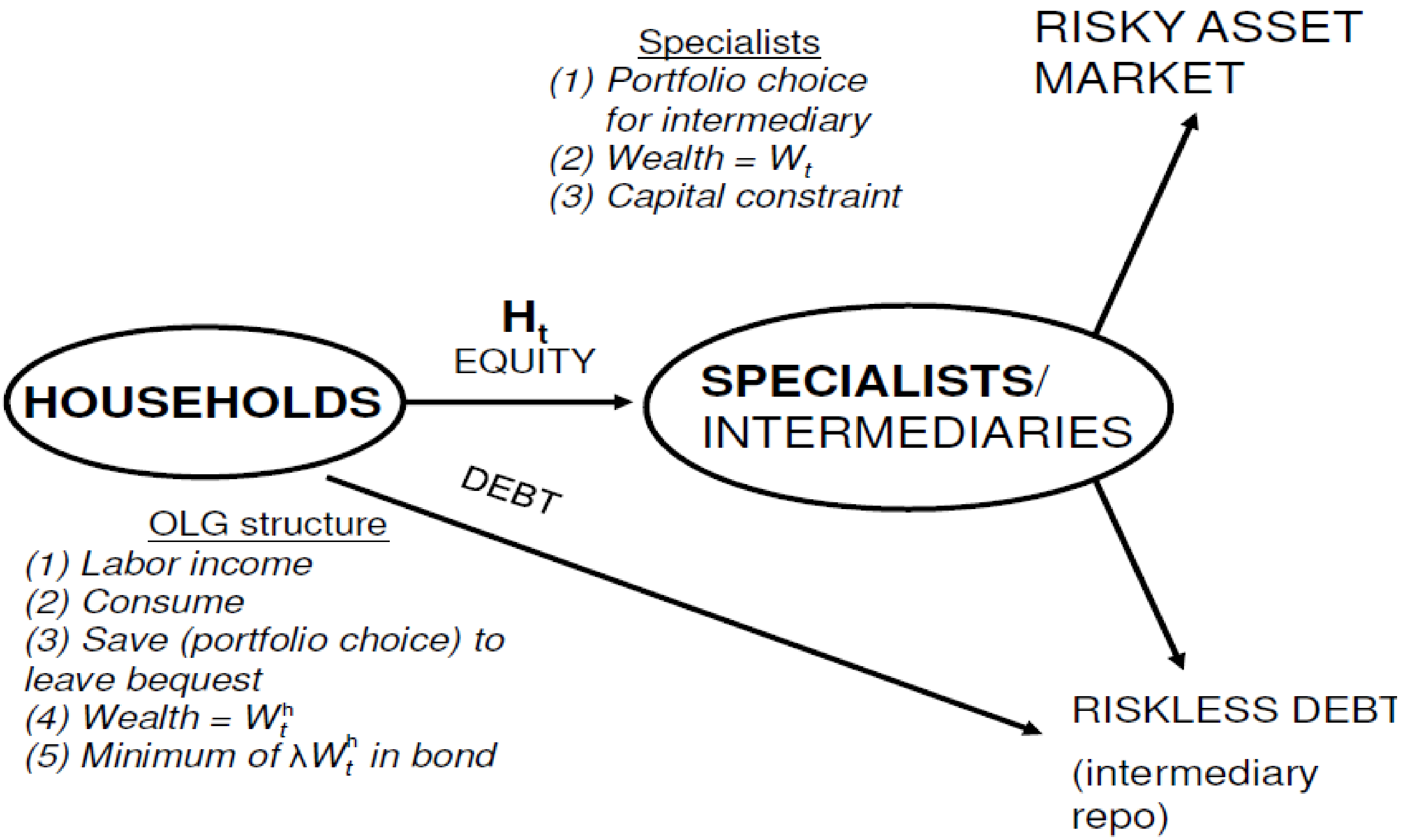
Model Structure



Model Structure

- Infinite horizon, continuous time economy with single perishable consumption good
- Households:
  - Limited participation in risky asset market
- Specialists:
  - Run intermediaries subject to an intermediation constraint
  - Household's investment cannot exceed a capacity, which is increasing in intermediary's (specialist's) capital
- Risky Asset:
  - *Illiquid* in the sense of market participation
- Riskless Asset:
  - *Liquid.* Debt, for convenience. In more general setting, can also be equity (ETFs, etc)
- Intermediaries, not households, are marginal in setting the price of the risky asset

Assets

- Continuous time, infinite horizon
- Risky Asset (unit supply) with dividend following a GBM:

$$\frac{dD_t}{D_t} = g\,dt + \sigma\,dZ_t$$

- Riskless short-term debt in zero net supply
- Risky asset price P_t and interest rate r_t are determined in equilibrium
- Total return on risky asset:

$$dR_t = \frac{D_t dt + dP_t}{P_t}$$

Intermediation

- Unit mass of identical, infinitely-lived specialists
- Maximize objective function

$$E\left[\int_0^{\infty} e^{-\rho t} u(c_t) dt\right]; \rho > 0$$

- CRRA instantaneous utility function $u(.)$
- Households can invest in the risky asset *indirectly* via intermediaries
- Match one specialist with one household to form "intermediary". Short-term intermediation relation (dt)
  - Specialist contributes all wealth w_t , and household chooses contribution $H_t \leq w_t^h$
  - The intermediary then invests in risky/riskless asset markets
  - Both parties share in the fund's return based on equity contributions
- "Risky return":

$$d\widetilde{R}_t = r_t dt + \alpha_t^I (dR_t - r_t dt)$$

Intermediary Capital Constraint

- Intermediation constraint: Household invests H_t, subject to

$$H_t \leq m\, w_t$$

  - Households require that managers have sufficient "skin in the game"
  - When a hedge fund loses a lot of money, managers' stake is depleted, and investors are reluctant to contribute further capital
  - Vice-versa: "Capital Shock"

- Interpretation of m:
  - Intermediary capital requirement: outside/inside contribution ratio
    - Officers/directors holdings of financial industry ~18% (Holderness, Kroszner, Sheehan 1999). Set $\frac{1}{1+m} = 0.18$, gives $m = 4.55$
  - Incentive contract — the performance share of hedge fund managers
    - Hedge fund manager receives $\frac{1}{1+m}$ of return of fund. The 20 in "2 and 20", gives $m = 4$

Capital Constraint: Example

- $m = 1$. Say $w_t^h = 80$
- Unconstrained Region: $w_t = 100$. Then $H_t = 80$
  - Fund's total equity 180. Risky asset price $P_t = 180$ (sum of w_t and w_t^h)
  - Fund invests 100% in risky asset. No leverage.
- Constrained Region: $w_t = 50$. Then $H_t = 50$
  - Fund's total equity is $50 + 50 = 100$. But $P_t = 130$
  - In equilibrium, the intermediary borrows 30 from the debt market
    - Supplied by households: $w_t^h - H_t = 30$
- Specialist and household have equal shares in the intermediary;
- Specialist's leveraged position in risky asset: $\alpha^I = \frac{50+15}{50} = 130\%$
- Risk premium has to adjust to make this portfolio choice optimal for the specialist.

Households

- Overlapping generations: Generation t born at t lives until $t + \delta$ ($\delta \to dt$)
- Born with wealth w_t^h and receives labor income flow of $l_t = lD_t$
- Utility:

$$\rho\delta \ln c_t^h + e^{-\rho\delta} E_t\left[v\left(w_{t+\delta}^h\right)\right]$$

  - $v(.)$ is the bequest function, assume $v(w) = \ln w$
  - Given log utility, optional consumption path is $c_t^h = \rho w_t^h$
- Two representative households
  - *Debt households:* fraction λ can only invest in risk-free bond
  - *Risk Asset household:* $(1 - \lambda)$ can invest in intermediary
    - $\alpha_t^h \in [0,1]$ is share of household wealth given to intermediary

Specialist Optimization

- The specialist chooses his consumption rate c_t , and the holding of the risky asset α_t^I (for the intermediary):

$$\max_{\{c_t,\alpha_t^I\}} E\left[\int_0^\infty e^{-\rho t} u(c_t)\, dt\right] s.t.\, dw_t = -c_t dt + w_t \widetilde{dR}_t(\alpha_t^I)$$

Where,

$$\widetilde{dR}_t = \alpha_t^I(dR_t - r_t dt) + r_t dt$$

Equilibrium

- An equilibrium is a set progressively measurable price processes $\{P_t\}$ and $\{r_t\}$, and $\{c_t, c_T^h, \alpha_t^I, H\_t \equiv \alpha_t^h w_t^h\}$ such that,
  - Given the price processes, decisions solve the consumption-savings problems of the households and the specialists
  - Decisions satisfy the intermediation constraint
  - The risky asset market clears:

$$\frac{\alpha_t^I\left(w_t + \alpha_t^h(1-\lambda)H_t\right)}{P_t} = 1;$$

  - The goods market clears:

$$c_t + c_t^h = D_t(1+l)$$

- Walras' Law: Bond market has to clear

Solutions

- Wealth distribution is key to the economy
- State variables: dividend D, and the specialist's wealth w.
  - Scale invariance. One dimensional state variable $\frac{w}{D}$.
- Specialist is always marginal in this economy (unconstrained portfolio choice problem). Use specialist's Euler equation to derive an ODE.
- Boundary condition as $w \to 0$. Reflecting barrier. Solved numerically.
- Solution: Capital Constraint binds at:

$$x_c = \frac{1-\lambda}{1-\lambda+m}; x = \frac{w_t}{P_t}$$

Solutions – Highlights

- Specialist is marginal investor. Faces no constraints. Portfolio choice must be an optimal choice for him.
- Thus, his Euler equation is always valid. Household is always constrained.
- Log utility for household means $c_t^h = \rho w_t^h$
- Goods market clearing then gives $c_t = (1 + l)D_t - c_t^h$
- Equilibrium specialist consumption into Euler equation ⇒ ODE for $F(y)$
- Close the loop: We can write dynamics of w_t^h as a function of returns (innovations in F(y)D), and household portfolio share α_t^h

Model and Reality: Rationale

Table 1: Intermediation Data[a]

Group	Assets[b]	Debt	Leverage
Commercial banks	11,800	10,401	0.88
S&L and Credit Unions	2,574	2,337	0.91
Property & Casualty Insurance	1,381	832	0.60
Life Insurance	4,950	4,662	0.94
Private Pensions	6,391	0	0.00
State & Local Ret Funds	3,216	0	0.00
Federal Ret Funds	1,197	0	0.00
Mutual Funds (excluding Money Funds)	7,829	0	0.00
Broker/Dealers	2,519	2,418	0.96
Hedge Funds	6,913	4,937	0.71

- Intermediaries account for over 60% of financial wealth

Model and Reality: Contrasts

- Model constrained region:

$$\alpha_t^{I,const} = \frac{1}{x_t}\frac{1}{1+m}; x_t = \frac{w_t}{P_t}$$

  – Negative shock ⇒ households withdraw ⇒ identical intermediaries lever up to clear market and earn risk premium

- Reality: Leverage and functional heterogeneity
  – Funds: Negative asset shock ⇒ households withdraw ⇒ sell assets/downsize
  – Insurance, Small Commercial Banks: Negative asset shock + leverage ⇒ bigger shocks ⇒ withdrawal, downsize
  – Bank traders: If others are downsizing ⇒ raise equity or lever up to clear market and earn risk premium

Model and Reality: Contrasts

- Model unconstrained region:

$$\alpha_t^{I,unconst} = \frac{1}{1-\lambda(1-x_t)}$$

  - Assume: $\alpha_t^h = 1$
  - λ fraction of households only demand debt (no intermediary investment)
  - Since intermediaries supply debt, controls leverage of intermediary in unconstrained region.
  - Choose λ= 0.6 to match unconstrained average leverage of 0.52 – which is the weighted average leverage from Table 1

$$\alpha_t^{I,const}/\alpha_t^{I,unconst} = \frac{1}{1+m}\left(1+(1-\lambda)\frac{1-\mathrm{x_t}}{\mathrm{x_t}}\right)$$

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Calibration Parameters

Table 2—Parameters and Targets

Panel A. Intermediation			
m	Intermediation multiplier	4	Compensation of financial managers
λ	Debt ratio	0.6	Debt/assets of intermediary sector
Panel B. Preferences and cashflows			
g	Dividend growth	2%	Growth of economy
σ	Dividend volatility	9%	Volatility of MBS portfolio
ρ	Time discount rate	4%	Short-term interest rate
γ	Relative risk aversion of specialist	2	Risk premium on MBS portfolio
l	Labor income ratio	1.84	Share of labor income in total income

- g from stock market, not critical
- $\sigma = 9\%$ is critical. It produces equilibrium return volatility between 9 and 9.5%.
- Volatility of returns on Agency MBS portfolio from 1976 to 2008 = 8.1%. CMBS portfolio from 1999 to 2008, return volatility = 9.6%.
- ρ to match average riskless interest rate around 0.5%
- γ= 2 matches avg. return on agency MBS portfolio of near 3%
- l chosen to match $E[(CapitalIncome)/(TotalIncome)]$ = 0.337 (from Parker-Vissing-Jorgensen)

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Risk Premia

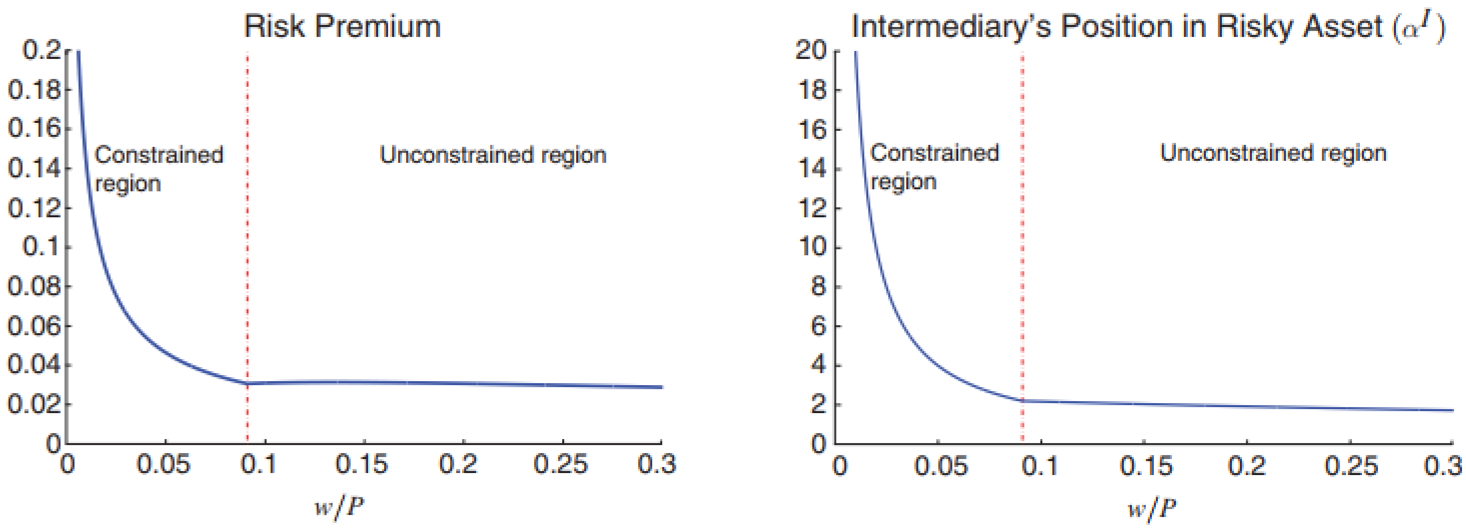

FIGURE 2. RISK PREMIUM

Notes: Risk premium and intermediary's portfolio share in the risky asset are graphed against $x = w/P$, the specialist's wealth as a percentage of the assets held by the intermediation sector. Parameters are those given in Table 2.

- Constraint binds when $mw_t < (1-\lambda)w_t^h$

Steady State Distribution

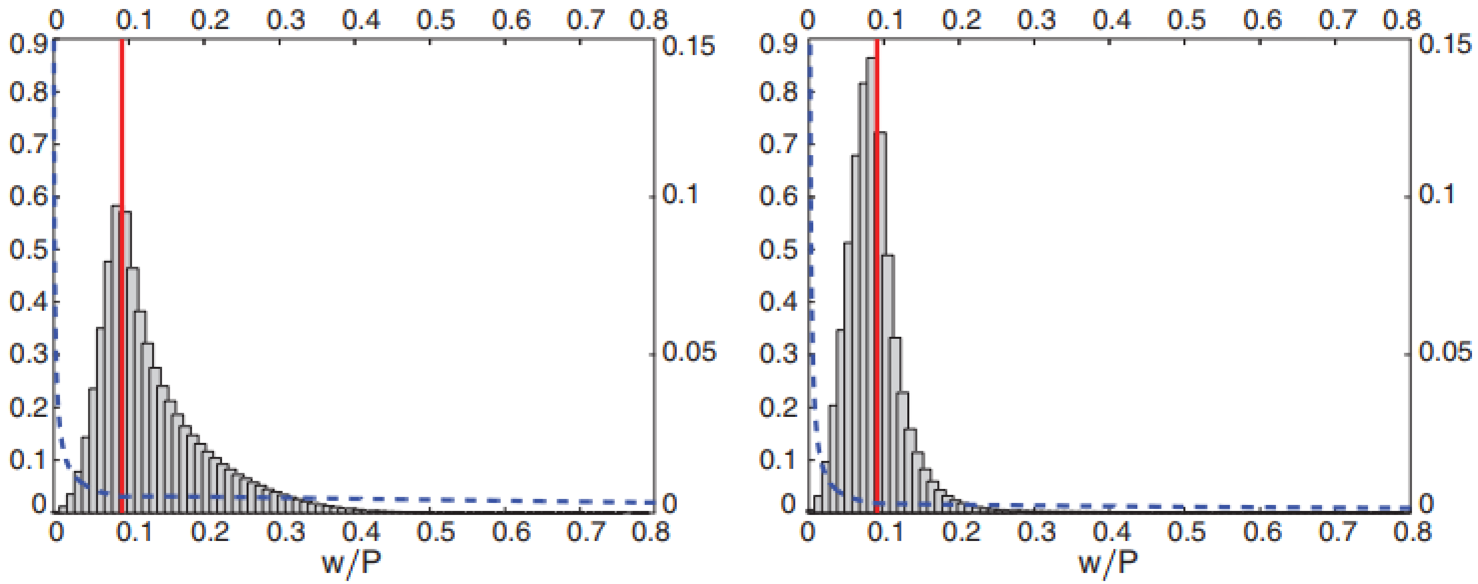

FIGURE 3. STEADY STATE DISTRIBUTION

Notes: The steady state distribution of $x = w/P$ is graphed. Left panel is for the baseline parameters, while right panel is for $\gamma = 1$. The vertical line at $x^c = \frac{1-\lambda}{1-\lambda+m}$ gives the state where the intermediation constraint starts binding. The dashed line graphs the risk premium in order to illustrate the actual range of variation of the risk premium. Risk premium is indicated on the left scale, while the distribution is indicated on the right scale.

Model Simulations

TABLE 3—MEASUREMENTS

	Baseline	$\sigma = 6$	$\gamma = 1$	$m = 8$	$\lambda = 0.05$	$l = 1$
Risk premium (%)	3.36	1.96	2.35	3.38	3.25	3.19
Sharpe Ratio (%)	36.46	32.62	27.34	37.11	35.72	34.81
Return volatility (%)	9.25	6.12	10.60	9.17	9.23	9.18
Interest rate (%)	0.06	1.42	0.95	0.02	0.14	0.83
Labor income ratio	0.64	0.52	0.54	0.62	0.55	0.61
Price/dividend	70.50	70.02	71.00	71.00	70.22	49.50
Prob(unconstrained)(%)	65.50	12.48	39.40	78.95	0.91	78.35
Debt/assets ratio (unconstrained)	0.50	0.49	0.52	0.52	0.00	0.48
Prob($RiskPremium > 2 \times \overline{RiskPremium}$)	0.87	1.99	3.49	0.55	1.43	0.57
E($RiskPremium \mid > 2 \times \overline{RiskPremium}$)	8.89	5.23	7.41	9.40	8.60	8.41

Notes: We present a number of key moments from the model. We report the unconditional average risk premium, Sharpe ratio, volatility, interest rate, and labor-to-total income ratio. We also report the unconditional probability of the capital constraint not binding, and the Debt/assets ratio of the intermediary sector conditional on the capital constraint not binding. The last two rows provide information on the tails of the distribution, where the risk premium is at least double its unconditional average. In the first column, we report measure for the baseline parameterization. The rest of the columns consider variations where we change a single parameter relative to the baseline given in Table 2.

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Crisis Episodes

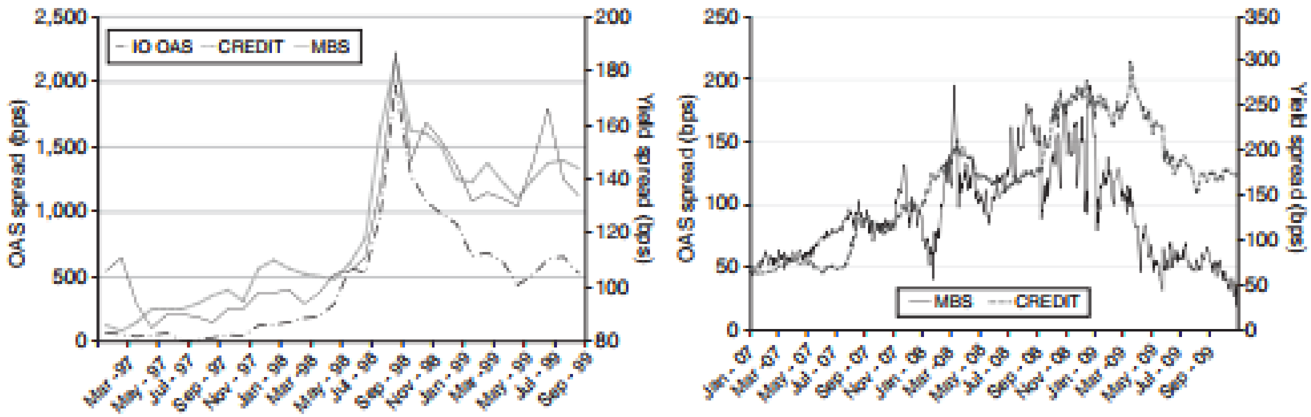

FIGURE 4. CRISIS SPREADS

Notes: The left panel graphs the spreads between the Moody's index of AAA corporate bonds and the ten-year Treasury rate (gray line, "credit"), the spreads between FNMA 6 percent TBA mortgage-backed securities and the ten-year Treasury rate (black line, "MBS"), and the option-adjusted spreads on a portfolio of interest-only mortgage-backed securities relative to Treasury bonds (dashed line, "IO OAS") from 1997 to 1999. The right panel graphs the same credit spread as well as the option adjusted spread on the FNMA 6 percent MBS from 2007 to 2009.

Crisis Episodes & Recovery

Table 4—Probability of Crisis

Risk premium (RP^*)	3.00%	6%	9%	12%
Panel A. Baseline				
Probability(risk premium $> RP^*$)	89.77	1.33	0.22	0.07
Sharpe ratio	32.31	66.26	103.59	144.04
Interest rate	0.48	−2.35	−5.47	−8.81
Debt/assets	45.63	82.66	90.28	93.57
Panel B. $\gamma = 1$				
Probability(risk premium $> RP^*$)	14.54	1.61	0.46	0.02
Sharpe ratio	33.34	66.68	100.02	133.36
Interest rate	0.41	−2.59	−5.59	−8.59
Debt/assets	73.03	86.53	91.03	93.28
Panel C. $m = 8$				
Probability(risk premium $> RP^*$)	93.16	1	0.19	0.06
Sharpe ratio	32.17	66.48	101.82	138.58
Interest rate	0.39	−2.5	−5.55	−8.7
Debt/assets	44.59	82.81	89.92	93.03

Notes: We condition on the state, or specialist capital, corresponding to given value of the risk premium, denoted RP^*. We report the probability that the risk premium exceeds RP^*, as well as the model's Sharpe ratio, interest rate, and intermediary debt/assets ratio at that value of RP^*. Panel A is for the baseline parameters, while the other panels are for variations where we change a single parameter.

Table 5—Crisis Recovery

Panel A. Baseline						
Transit to	10	7.5	6	5	4	3.5
Transit time from 12	0.18	0.65	1.42	2.67	5.56	9.34
Increment time	0.18	0.47	0.77	1.25	2.90	3.78
Panel B. $\gamma = 1$						
Transit time from 12	0.12	0.37	0.71	1.15	2.02	2.85
Increment time	0.12	0.25	0.34	0.43	0.88	0.82
Panel C. $m = 8$						
Transit time from 12	0.16	0.60	1.31	2.41	5.28	8.78
Increment time	0.16	0.44	0.71	1.10	2.87	3.49

Notes: This table presents transition time data from simulating the model. We fix a state corresponding to an instantaneous risk premium of 12 percent ("Transit from"). Simulating the model from that initial condition, we compute and report the first passage time that the state hits the risk premium corresponding to that in the "Transit to" row. Time is reported in years. The row "Increment time" reports the time between incremental "Transit to" rows. Data is presented for the baseline parameters and two variations.

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Borrowing Subsidy

- Suppose we are currently in the extreme crisis state with risk premium of 12%. The government offers a loan subsidy to intermediaries on all of their borrowings, of size Δr. Households are taxed, and government makes a lump sum transfer of

$$\Delta r \times (\alpha_t^I - 1) w_t dt$$

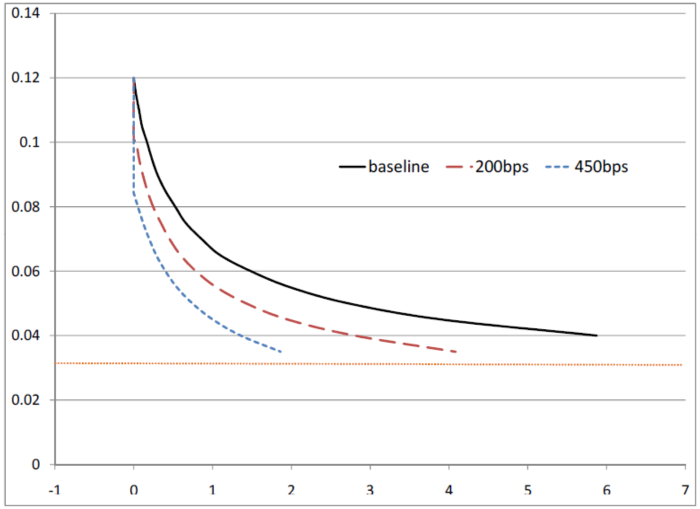

TABLE 6—BORROWING SUBSIDY

Transit to	$\Delta r = 0$	$\Delta r = 0.01$	$\Delta r = 0.02$	$\Delta r = 0.045$
		10.85%	9.82%	7.94%
10.00%	0.18	0.08		
7.50%	0.65	0.45	0.18	0.08
6.00%	1.42	1.04	0.65	0.37
5.00%	2.67	1.85	1.42	0.70
4.00%	5.56	3.74	2.67	1.29

Notes: This table presents transition time data from simulating the model. We begin in the 12 percent risk premium state and report the first passage time for the state to reach that in the first column of the table ("Transit to" column). Time is reported in years. We report the case of no subsidy ($\Delta r = 0$), as well as subsidies of 0.01, 0.02, and 0.045. A subsidy of 0.01 corresponds to 100 bps. The first row of the table reports the instantaneous jump downward in the risk premium when the government initiates the policy. The simulation is for the baseline parameters.

Direct Asset Purchase

- Government finances the purchase of fraction s of the risky asset, in unconstrained states, by issuing sP_t of short-term debt

TABLE 7—ASSET PURCHASE

Transit to	$s = 0$	$s = 0.04$	$s = 0.08$	$s = 0.12$
		11.43%	10.85%	10.25%
10.00%	0.18	0.14	0.10	0.05
7.50%	0.65	0.61	0.58	0.52
6.00%	1.42	1.39	1.32	1.27
5.00%	2.67	2.51	2.48	2.40
4.00%	5.56	5.50	5.48	5.37

Notes: This table presents transition time data from simulating the model. We begin in the 12 percent risk premium state and report the first passage time for the state to reach that in the first column of the table ("Transit to" column). Time is reported in years. We report the case of no purchase ($s = 0$), as well as purchases of 0.04, 0.08, and 0.12. A purchase with $s = 0.04$ corresponds to the government buying 4 percent of the outstanding stock of intermediated risky assets. The first row of the table reports the instantaneous jump downward in the risk premium when the government begins its purchase.

Capital Infusion

- Government acquires preferred shares in intermediaries, increasing m to $\overline{m}$.
- Faster transition to lower risk premia than Direct purchase or subsidy.

TABLE 8—EQUITY INJECTION

Transit to	Baseline	$38 billion	$48 billion	$58 billion
		9.57%	9.05%	8.57%
10.00%	0.18			
7.50%	0.65	0.43	0.37	0.27
6.00%	1.42	1.19	1.10	0.99
5.00%	2.67	2.35	2.24	2.14
4.00%	5.56	5.23	5.01	4.95

Notes: This table presents transition time data from simulating the model. We begin in the 12 percent risk premium state and report the first passage time for the state to reach that in the first column of the table ("Transit to" column). Time is reported in years. We report the case of a purchase of equity capital of $38 billion, $48 billion, and $58 billion, which is reversed in roughly one year. The first row of the table reports the instantaneous jump downward in the risk premium when the government injects the equity capital.

Conclusion

- Model is canonical and fairly tractable. Performs well in:
  - Nonlinearity of risk premia in crisis episodes
  - Recovery time from crises
- Equity pricing literature tells us that low probability bad states have disproportionate effect on average pricing.

Pradeep Muthukrishnan
PhD Student (Finance)
Samuel Curtis Johnson Graduate School of Management
Cornell SC Johnson College of Business

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