Intermediary Asset Pricing

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
Outline

• The Model
• Calibration
• Crisis Episode
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Model Structure

Specialists
(1) Portfolio choice for intermediary
(2) Wealth = \( W_i \)
(3) Capital constraint

HOUSEHOLDS

SPECIALISTS/INTERMEDIARIES

RISKY ASSET MARKET

RISKLESS DEBT
(intermediary repo)

OLG structure
(1) Labor income
(2) Consume
(3) Save (portfolio choice) to leave bequest
(4) Wealth = \( W_i^h \)
(5) Minimum of \( \lambda W_i^h \) in bond
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”:
  \[ d\bar{R}_t = r_t dt + \alpha_t^l (dR_t - r_t dt) \]
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 $\sim 18\%$ (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 $t + \delta$ ($\delta \rightarrow dt$)

- Born with wealth $w_t^h$ and receives labor income flow of $l_t = lD_t$

- Utility:
  \[
  \rho \delta \ln c_t^h + e^{-\rho \delta} E_t[v(w_{t+\delta}^h)]
  \]
  - $v(.)$ 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 $\lambda$ 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 $\alpha^I_t$ (for the intermediary):

\[
\max_{\{c_t, \alpha^I_t\}} E \left[ \int_0^\infty e^{-\rho t} u(c_t) \, dt \right] \quad s.t. \quad dw_t = -c_t \, dt + w_t \, d\widetilde{R}_t(\alpha^I_t)
\]

Where,

\[
d\widetilde{R}_t = \alpha^I_t (dR_t - r_t \, dt) + r_t \, dt
\]
Equilibrium

- An equilibrium is a set progressively measurable price processes \(\{P_t\}\) and \(\{r_t\}\), and \(\{c_t, c^h_t, \alpha_t^l, H_t \equiv \alpha_t^h w^h_t\}\) 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:
    \[ \frac{\alpha_t^l (w_t + \alpha_t^h (1 - \lambda) H_t)}{P_t} = 1; \]
  - The goods market clears:
    \[ c_t + c^h_t = D_t (1 + l) \]
- 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 $\Rightarrow$ 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 $\alpha_t^h$
Model and Reality: Rationale

Table 1: Intermediation Data

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

- Intermediaries account for over 60% of financial wealth
Model and Reality: Contrasts

• Model constrained region:

\[
\alpha_t^{I, \text{const}} = \frac{1}{x_t} \frac{1}{1 + m}; \quad x_t = \frac{w_t}{P_t}
\]

  - 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:

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

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

\[ \frac{\alpha_t^{I,\text{const}}}{\alpha_t^{I,\text{unconst}}} = \frac{1}{1 + m} (1 + (1 - \lambda) \frac{1 - x_t}{x_t}) \]
Outline

• The Model
• Calibration
• Crisis Episode
  – Crisis risk premia and flight to quality
  – Crisis recovery
• Policy Experiments
Calibration Parameters

<table>
<thead>
<tr>
<th>Panel A. Intermediation</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$m$</td>
<td>Intermediation multiplier</td>
<td>4</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>Debt ratio</td>
<td>0.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel B. Preferences and cashflows</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$g$</td>
<td>Dividend growth</td>
<td>2%</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>Dividend volatility</td>
<td>9%</td>
</tr>
<tr>
<td>$\rho$</td>
<td>Time discount rate</td>
<td>4%</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Relative risk aversion of specialist</td>
<td>2</td>
</tr>
<tr>
<td>$l$</td>
<td>Labor income ratio</td>
<td>1.84</td>
</tr>
</tbody>
</table>

- $g$ 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%.
- $\rho$ to match average riskless interest rate around 0.5%
- $\gamma = 2$ matches avg. return on agency MBS portfolio of near 3%
- $l$ chosen to match $E[(CapitalIncome)/(TotalIncome)] = 0.337$ (from Parker-Vissing-Jorgensen)
Outline

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Risk Premia

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

**Figure 3. Steady State Distribution**

*Notes:* The steady state distribution of \( x = \frac{w}{P} \) is graphed. Left panel is for the baseline parameters, while right panel is for \( \gamma = 1 \). The vertical line at \( x^c = \frac{1-\lambda}{1-\lambda+\mu} \) 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

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

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.
Outline

• The Model

• Calibration

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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

<table>
<thead>
<tr>
<th>Risk premium ($RP^*$)</th>
<th>3.00%</th>
<th>6%</th>
<th>9%</th>
<th>12%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A. Baseline</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 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 | 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

<table>
<thead>
<tr>
<th></th>
<th>Transit to</th>
<th>Transit time from 12</th>
<th>Increment time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A. Baseline</strong></td>
<td>10</td>
<td>7.5</td>
<td>6</td>
</tr>
<tr>
<td>Transit time from 12</td>
<td>0.18</td>
<td>0.65</td>
<td>1.42</td>
</tr>
<tr>
<td>Increment time</td>
<td>0.18</td>
<td>0.47</td>
<td>0.77</td>
</tr>
<tr>
<td><strong>Panel B. $\gamma = 1$</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transit time from 12</td>
<td>0.12</td>
<td>0.37</td>
<td>0.71</td>
</tr>
<tr>
<td>Increment time</td>
<td>0.12</td>
<td>0.25</td>
<td>0.34</td>
</tr>
<tr>
<td><strong>Panel C. $m = 8$</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transit time from 12</td>
<td>0.16</td>
<td>0.60</td>
<td>1.31</td>
</tr>
<tr>
<td>Increment time</td>
<td>0.16</td>
<td>0.44</td>
<td>0.71</td>
</tr>
</tbody>
</table>

**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 $\Delta r$. Households are taxed, and government makes a lump sum transfer of

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

<table>
<thead>
<tr>
<th>Transit to</th>
<th>$s = 0$</th>
<th>$s = 0.04$</th>
<th>$s = 0.08$</th>
<th>$s = 0.12$</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.00%</td>
<td>0.18</td>
<td>0.14</td>
<td>0.10</td>
<td>0.05</td>
</tr>
<tr>
<td>7.50%</td>
<td>0.65</td>
<td>0.61</td>
<td>0.58</td>
<td>0.52</td>
</tr>
<tr>
<td>6.00%</td>
<td>1.42</td>
<td>1.39</td>
<td>1.32</td>
<td>1.27</td>
</tr>
<tr>
<td>5.00%</td>
<td>2.67</td>
<td>2.51</td>
<td>2.48</td>
<td>2.40</td>
</tr>
<tr>
<td>4.00%</td>
<td>5.56</td>
<td>5.50</td>
<td>5.48</td>
<td>5.37</td>
</tr>
</tbody>
</table>

*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 $\bar{m}$.
- Faster transition to lower risk premia than Direct purchase or subsidy.

### Table 8—Equity Injection

<table>
<thead>
<tr>
<th>Transit to</th>
<th>Baseline</th>
<th>$38\text{ billion}$</th>
<th>$48\text{ billion}$</th>
<th>$58\text{ billion}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.00%</td>
<td>0.18</td>
<td>9.57%</td>
<td>9.05%</td>
<td>8.57%</td>
</tr>
<tr>
<td>7.50%</td>
<td>0.65</td>
<td>0.43</td>
<td>0.37</td>
<td>0.27</td>
</tr>
<tr>
<td>6.00%</td>
<td>1.42</td>
<td>1.19</td>
<td>1.10</td>
<td>0.99</td>
</tr>
<tr>
<td>5.00%</td>
<td>2.67</td>
<td>2.35</td>
<td>2.24</td>
<td>2.14</td>
</tr>
<tr>
<td>4.00%</td>
<td>5.56</td>
<td>5.23</td>
<td>5.01</td>
<td>4.95</td>
</tr>
</tbody>
</table>

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 $38\text{ billion}$, $48\text{ billion}$, and $58\text{ billion}$, 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.
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