OR's Role in Risk Management in the Aftermath of the Financial Crisis

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Theme

• There is a lot of blame to go around
• Quants (OR) played some role but...
  – Good OR models could have helped
  – OR models can help more
• Many new research questions
• Many new opportunities for OR/risk management in practice
The Worst Crisis since..ever?

Relative Dow Jones IA over 2 years:

Which line is from 1929-1931 and which is from 2007-2009?
Dow Jones path: 80 years ago and today

Only the losses in the Great Depression rivaled the loss in equity value during the current crisis.
DJIA from 10/2007 to 3/2009: -52%
Worst all-time 17 months: (1/1931 to 6/1932): -75%
Down Across Sectors

Financial Assets - U.S. Households and Non-Profit Organizations ($ Trillions)

Net Worth – U.S. Households and Non-Profit Organizations ($ Trillions)

Corporate Equities (Stocks) Held by U.S. Households and Non-Profit Organizations Market Value ($ Trillions)

U.S. Household Real Estate ($ Trillions - Bars/Left Axis) And Owners Equity as % Real Estate Value (Right Axis/Line)

Source Data: Federal Reserve Flow of Funds Report Q1 2009
Why the Worst Losses in 70 Years?

Outline:

• Who is to blame?
  – Consumers?
  – Lenders?
  – Insurers?
  – Raters?

• Answer: Yes.. but where can OR help?

• Where do we go next?
Consumers took on excessive debt using inflated home prices as collateral, causing a bubble that inevitably burst.

True? If so, why? Can OR help?
Net Equity Extracted

Source: Greenspan and Kennedy (Fed 2005-7)
Chart in: Gorton, 2008,
http://www.som.yale.edu/faculty/gbg24/Panic%20of%202007.pdf
New Mortgages

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Mortgage Originations (Billions)</th>
<th>Subprime Originations (Billions)</th>
<th>Subprime Share in Total Originations (% of dollar value)</th>
<th>Subprime Mortgage Backed Securities (Billions)</th>
<th>Percent Subprime Securitized (% of dollar value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>$2,215</td>
<td>$190</td>
<td>8.6%</td>
<td>$95</td>
<td>50.4%</td>
</tr>
<tr>
<td>2002</td>
<td>$2,885</td>
<td>$231</td>
<td>8.0%</td>
<td>$121</td>
<td>52.7%</td>
</tr>
<tr>
<td>2003</td>
<td>$3,945</td>
<td>$335</td>
<td>8.5%</td>
<td>$202</td>
<td>60.5%</td>
</tr>
<tr>
<td>2004</td>
<td>$2,920</td>
<td>$540</td>
<td>18.5%</td>
<td>$401</td>
<td>74.3%</td>
</tr>
<tr>
<td>2005</td>
<td>$3,120</td>
<td>$625</td>
<td>20.0%</td>
<td>$507</td>
<td>81.2%</td>
</tr>
<tr>
<td>2006</td>
<td>$2,980</td>
<td>$600</td>
<td>20.1%</td>
<td>$483</td>
<td>80.5%</td>
</tr>
</tbody>
</table>


Table: Gorton, 2008,  
http://www.som.yale.edu/faculty/gbg24/Panic%20of%202007.pdf
Borrowing versus Home Value  
(Mian/Sufi 2009)

Table III  
The Effect of House Prices on Household Borrowing for 1997 Homeowners, Dollar for Dollar Changes

This table presents estimates of the effect of house prices on household borrowing for individuals who have either an existing mortgage account with positive balance as of 1997 or a previous mortgage account. Individual dummy variables are quintile indicator variables for 2% bins of the 1997 credit score, 2008 income, and 1997 age variables. Census controls are zip code level variables for the vacancy rate, fraction white, fraction black, education indicator variables for less than high school and high school diploma only, the unemployment rate, the poverty rate, and the fraction of households in the zip code living in an urban setting, all measured as of 2000. Income controls are zip code level variables from the IRS and Census business statistics for the logarithm of the 2002 employment, per capita wage, and per capita payroll level, and the growth in wage, payroll and employment from 1997 to 2000, 2000 to 2002, and 2002 to 2006. All standard errors are clustered at the MSA level. All standard errors are clustered at the MSA level.

<table>
<thead>
<tr>
<th>Left hand side variable</th>
<th>(1) Change in home value 2002-2006 $thousands</th>
<th>(2) Change in total debt 2002-2006 $thousands</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housing supply inelasticity</td>
<td>63.433** (17.773)</td>
<td>0.245** (0.051)</td>
<td>0.298** (0.056)</td>
<td>0.302** (0.056)</td>
</tr>
<tr>
<td>Instrumented change in home value, 2002-2006</td>
<td>0.464** (0.112)</td>
<td>0.017 (0.042)</td>
<td>-0.028 (0.055)</td>
<td>-0.030 (0.051)</td>
</tr>
<tr>
<td>Median home value, 2002</td>
<td>(Credit score, 1997)/100</td>
<td>25.425** (4.770)</td>
<td>-6.902** (1.092)</td>
<td></td>
</tr>
<tr>
<td>Additional control variables</td>
<td></td>
<td>Individual dummy variables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>12152</td>
<td>12152</td>
<td>12137</td>
<td>12137</td>
</tr>
<tr>
<td>R^2</td>
<td>0.57</td>
<td>0.03</td>
<td>0.06</td>
<td>0.08</td>
</tr>
</tbody>
</table>

**, *, + coefficient statistically distinct from 0 at the 1, 5, and 10% level, respectively.

Consumer Effects

• Consumers increased borrowing against home value
• More consumers with lower credit histories entered the market
• Wide use of low-interest loans (ARMs)
• Was it irrational?
Where can OR help?

• Personal lifetime investment tools based on:
  – Stochastic modeling
  – Simulation
  – Optimization
• Easy-to-use analysis based to individual
• Understandable results to help in household decision making
Government caused Crisis?

The federal government caused the crisis by overly stimulating housing bubble through low interest rates and policies to promote home ownership.

True? How were interest rates related to the crisis?
Interest Rates and Delinquency

Delinquency in subprime ARMs, subprime FRMS, prime ARMS, (Source: MBAA) and 10 times Prime Rate – 2004 rate (Federal Reserve).
Other Government Impacts

• Fannie Mae and Freddie Mac lending and securitizing (use of scoring systems)
• Guarantees against agency lending
• Income tax incentives
• Rescues of the “too big to fail” (and moral hazard effects)
• Regulatory requirements, supervision, and enforcement
Possible OR Improvements

- Better analysis of impact on individual behavior
- Improved classification of risk in mortgage pools
- Assessment of overall effects from multiple agent interactions
- Dynamic (flexible) models for adjustment of regulatory capital requirements
Were Lenders the Cause?

Lenders excessively extended credit to high-risk consumers.

True? Were there borrowers who should not have been in the pool?
Borrowing versus Subprime Fraction (Mian/Sufi 2009)

Table IV
Mortgage Credit Expansion in Subprime Zip Codes:

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fraction of subprime borrowers, 1996</td>
<td>0.460**</td>
<td>0.458**</td>
<td>0.454**</td>
<td>0.431**</td>
<td>0.060**</td>
</tr>
<tr>
<td>Income growth, 2002 to 2005</td>
<td>(0.033)</td>
<td>(0.033)</td>
<td>(0.035)</td>
<td>(0.079)</td>
<td>(0.015)</td>
</tr>
<tr>
<td>Establishment growth, 2002 to 2005</td>
<td>-0.064</td>
<td>-0.068</td>
<td>-0.084</td>
<td>0.145</td>
<td>0.360**</td>
</tr>
<tr>
<td>Employment growth, 2002 to 2005</td>
<td>(0.097)</td>
<td>(0.097)</td>
<td>(0.104)</td>
<td>(0.223)</td>
<td>(0.044)</td>
</tr>
<tr>
<td>Crime growth, 2002 to 2005</td>
<td>0.084</td>
<td>0.096</td>
<td>0.118</td>
<td>-1.898**</td>
<td>0.805**</td>
</tr>
<tr>
<td>House price elasticity with respect to income</td>
<td>(0.124)</td>
<td>(0.127)</td>
<td>(0.142)</td>
<td>(0.314)</td>
<td>(0.058)</td>
</tr>
<tr>
<td>House quantity elasticity with respect to income</td>
<td>(0.056)</td>
<td>(0.056)</td>
<td>(0.056)</td>
<td>(0.101)</td>
<td>(0.026)</td>
</tr>
<tr>
<td>Fraction of housing units vacant, 2000</td>
<td>0.015</td>
<td>0.012</td>
<td>0.012</td>
<td>0.551</td>
<td>0.251*</td>
</tr>
<tr>
<td>Fraction of housing stock built last 2 years, 2000</td>
<td>(0.078)</td>
<td>(0.256)</td>
<td>(0.278)</td>
<td>(0.779)</td>
<td>(0.117)</td>
</tr>
<tr>
<td>Fraction of housing stock built 2 to 5 years ago, 2000</td>
<td>0.363</td>
<td>1.161</td>
<td>0.363</td>
<td>1.161</td>
<td>0.363</td>
</tr>
<tr>
<td>N</td>
<td>2946</td>
<td>2946</td>
<td>2782</td>
<td>2782</td>
<td>2946</td>
</tr>
<tr>
<td>R²</td>
<td>0.42</td>
<td>0.42</td>
<td>0.45</td>
<td>0.94</td>
<td>0.33</td>
</tr>
</tbody>
</table>

This table presents coefficient estimates from specifications relating the growth in mortgage origination for home purchase in a zip code from 2002 to 2005 to the fraction of subprime borrowers in 1996. Column (5) examines the growth in total mortgage debt, and column (6) examines the growth in non-home consumer debt. The measure of house price elasticity (house quantity elasticity) uses changes in median house value (number of owner occupied housing units) from 1990 to 2000 from the decennial census, and changes in household income from 1991 to 2001 from the IRS. All growth rates are annualized. All specifications include county fixed effects except for the specification reported in column (4), which includes 3 square mile fixed effects. ** * Coefficient estimate statistically distinct from 0 at the 1% and 5% levels, respectively.

Did Lenders Try to Pass along Risk with Securitization? (Keys, Mukherjee, Seru, Vig (2008))

- Loans with FICO above 620 twice as likely to be securitized as those below 620
- Significantly more low-documentation loans at 620+
- Higher rates of delinquency

How Can OR Help?

- Better credit scoring systems
- Improved classification systems on other characteristics
- Improved analysis of other effects on consumers (rates, housing prices, etc.)
Did Securitizers cause the Crisis?

Securitizers bundled loans together into complex asset-backed securities that were valued much higher than they were worth.

True? What happened to the prices of these securities?
Securitized Products

- Collateralized Debt Obligations (CDOs): Re-organize debt by losses due to default

Promised payments

CDO Tranches:
- First 3% of losses: Equity
- 3-7% of losses: 1st Mezzanine
- 7-10% of losses: 2nd Mezzanine
- 10-15% of losses: Mezzanine
- 15-30% of losses: Senior
- Super Senior

Some may default, then collect collateral.
ABS Prices (Gorton (2008))

What Makes them Complex?

• Interactions among the causes of risk
• Uncertainty about composition of the pool
• Contingent losses on previous loss
• Risk in default, prepayment, and loss-given-default (recovery of collateral)
• Difficulty to price elements together in the market
OR Assistance?

- Develop better models for pricing ABSs
- More capabilities for multiple risk categories
- Better classification
- Improved incorporation into pools of other assets for overall risk assessment
Did Insurers cause the Crisis?

*Insurers sold policies to cover losses that they did not have the capacity to cover.*

- True? What did they do? What can help them out?
# AIG's Income Statement

(Sjostrom (2008))

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Revenues</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General Insurance</td>
<td>$35,854</td>
<td>$51,708</td>
<td>$49,206</td>
<td>$45,174</td>
</tr>
<tr>
<td>Life Insurance &amp; Retirement</td>
<td>14,271</td>
<td>53,570</td>
<td>50,878</td>
<td>48,020</td>
</tr>
<tr>
<td>Financial Services</td>
<td>(16,016)</td>
<td>(1,309)</td>
<td>7,777</td>
<td>10,677</td>
</tr>
<tr>
<td>Asset Management</td>
<td>658</td>
<td>5,625</td>
<td>4,543</td>
<td>4,582</td>
</tr>
<tr>
<td>Other</td>
<td>531</td>
<td>457</td>
<td>483</td>
<td>344</td>
</tr>
<tr>
<td>Consolidation &amp; Eliminations</td>
<td>(436)</td>
<td>13</td>
<td>500</td>
<td>(16)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$34,862</td>
<td>$110,064</td>
<td>$113,387</td>
<td>$108,781</td>
</tr>
</tbody>
</table>

| **Operating Income (Loss)** |                            |       |       |       |
| General Insurance           | $(393)                     | $10,562 | $10,412 | $2,315 |
| Life Insurance & Retirement| (19,561)                   | 8,186  | 10,121 | 8,965  |
| Financial Services          | (22,880)                   | (9,515) | 383    | 4,424  |
| Asset Management            | (2,709)                    | 1,164  | 1,538  | 1,963  |
| Other                       | (2,899)                    | (2,140) | (1,435) | (2,765) |
| Consolidation & Eliminations| 237                        | 722    | 668    | 311    |
| **Total**                   | $(48,205)                  | $8,943 | $21,687 | $15,213 |

CDS Insurance – AIG story

• Protect against default on the underlying securities
• AIG sold $526 billion in CDSs
• Many at AAA level (1 in 10,000 default odds?)
• Problems? Large collateral requirement changes (+$6B in one month out of $18B for all uses)
Where can OR help?

• Improved assessment of tail risk phenomena?
• Better risk characterization for collateral needs
• Dynamic assessment of risk portfolio and capital needs
Were the Raters to Blame?

Rating agencies gave securities overly optimistic ratings that did not reflect reality.

- True? What did they do? Why? Can OR help?
Repo Rate Haircuts

(Gorton (2008))

Table 1: Repurchase Agreement (Repo) Market Haircuts during the Crisis*

<table>
<thead>
<tr>
<th>Asset Class**</th>
<th>July '07 Pre-Crisis</th>
<th>Late July-August</th>
<th>Q3 2007</th>
<th>Q4 2007</th>
<th>Q1 2008</th>
<th>Q2 2008</th>
<th>Q2→Current*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corporates A-AA rated</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Corporates BBB rated</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0-5%</td>
</tr>
<tr>
<td>Corporates &lt; BBB-rated</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0-5%</td>
</tr>
<tr>
<td>ABS AA-AA *</td>
<td>0%</td>
<td>2-5%</td>
<td>3-7%</td>
<td>5-10%</td>
<td>10-15%</td>
<td>15-20%</td>
<td>20-25%</td>
</tr>
<tr>
<td>ABS BBB-AA</td>
<td>0%</td>
<td>3-7%</td>
<td>5-10%</td>
<td>10-15%</td>
<td>15-20%</td>
<td>20-25%</td>
<td>20-30%</td>
</tr>
<tr>
<td>ABS &lt; BBB</td>
<td>0-2%</td>
<td>5-10%</td>
<td>10-15%</td>
<td>15-20%</td>
<td>20-25%</td>
<td>No financing</td>
<td>No financing</td>
</tr>
<tr>
<td>CLO, Other AA-AAA</td>
<td>0%</td>
<td>2-5%</td>
<td>3-7%</td>
<td>5-10%</td>
<td>10-15%</td>
<td>15-20%</td>
<td>20-25%</td>
</tr>
<tr>
<td>CLO, Other BBB-AA</td>
<td>0%</td>
<td>3-7%</td>
<td>5-10%</td>
<td>10-15%</td>
<td>15-20%</td>
<td>20-25%</td>
<td>20-30%</td>
</tr>
<tr>
<td>CLO, Other &lt; BBB</td>
<td>0-2%</td>
<td>5-10%</td>
<td>10-15%</td>
<td>15-20%</td>
<td>20-25%</td>
<td>No financing</td>
<td>No financing</td>
</tr>
<tr>
<td>CMO, Other AA-AAA</td>
<td>0%</td>
<td>3-7%</td>
<td>4-8%</td>
<td>5-10%</td>
<td>10-20%</td>
<td>20-25%</td>
<td>No financing</td>
</tr>
<tr>
<td>CMO, Other BBB-AA</td>
<td>0%</td>
<td>3-7%</td>
<td>5-10%</td>
<td>10-20%</td>
<td>20-25%</td>
<td>20-25%</td>
<td>No financing</td>
</tr>
<tr>
<td>CMO, Other &lt; BBB</td>
<td>0-2%</td>
<td>5-10%</td>
<td>10-20%</td>
<td>20-25%</td>
<td>No financing</td>
<td>No financing</td>
<td>No financing</td>
</tr>
<tr>
<td>CDO AA-AAA</td>
<td>0%</td>
<td>3-7%</td>
<td>5-10%</td>
<td>10-20%</td>
<td>15-20%</td>
<td>15-20%</td>
<td>15-20%</td>
</tr>
<tr>
<td>CDO BBB-AA</td>
<td>0%</td>
<td>5-10%</td>
<td>10-15%</td>
<td>15-25%</td>
<td>20-30%</td>
<td>25-30%</td>
<td>No financing</td>
</tr>
<tr>
<td>CDO &lt; BBB</td>
<td>0-2%</td>
<td>10%+</td>
<td>15-20%</td>
<td>25-30%</td>
<td>No financing</td>
<td>No financing</td>
<td>No financing</td>
</tr>
</tbody>
</table>

Source: Repo trader.

Overall Effects

• Senior tranches were given high ratings that ultimately did not correspond to their market prices
• Difficulties in assessing the securities
• Problems in terms of rating as “any losses” versus actual or expected losses
Opportunities for OR

• Create better modeling systems
• Incorporate multiple correlations into assessment
• Devise better rating systems overall for individual, institutional, and sovereign ratings
Did Investors cause the Crisis?

Individual investors inflated security prices by buying with excess credit and institutional investors dried up liquidity by enforcing quality guidelines (e.g., marking-to-market) in extreme conditions.

True? Opportunities?
Opportunities for OR?

• Develop better risk management models to allow consideration of overall goals:
  – Proper investments for individuals
  – Flexible guidelines for institutions
  – Dynamic requirements from regulators
But..in the end, weren't the Modelers to Blame?

Risk managers and quantitative analysts used unrealistic assumptions about correlation and price trends in building overly optimistic models.

• True? Yes, *mea culpa*, but we can do a lot to improve the financial system going forward .. needs?
Modeling Needs Going Forward

• Specific risk and interaction considerations that appeared here
• Better overall awareness of model risk (and other forms of risk only captured implicitly)
• Healthy degrees of skepticism
• Views of multiple interacting agents
Implications of Models: Multiple Interconnections

CDO Issuer

CDS Issuer

CDO Issuer

CDS Issuer

CDO Issuer

CDS Issuer

CDO Issuer

CDS Issuer

Loan obligors

Loan obligors

Loan obligors
A Few Research Topics

• Better discretization methods (FEM v. finite differences)
• On-line (continual) optimization for real-time applications
• Inclusion of incomplete markets – distributed optimization
• Consideration of taxes – non-convex and discrete optimization
• Integration of stochastic model/simulation and optimization
Conclusions

• Each of the participants in the financial system has some share of the blame
• Better use of OR models and tools can help alleviate these problems in the future
• We need to ensure that all who use these models and tools are aware of their limitations
• We have many research topics to consider and much to contribute to sustained growth without new crises
Thank you!

Questions?