Correlation of Risks, Integrating Risk Measurement – Risk Aggregation

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Statement of the Problem:
Need for a New Approach to ERM

- What is Enterprise Risk Management?
  - Aggregating balance sheet risk?
  - Aggregating VaR and EaR of the enterprise?
  - Assigning economic capital to business units?
- An enterprise is a portfolio of businesses, not just assets and liabilities
  - How do you manage the risk of a portfolio of businesses?
Contributions of the Presentation

- Describes a very comprehensive approach for aggregating the risks for the enterprise
  - Valuation – new modeling results
  - Simulation – credit and market risks
  - Aggregating business risks
- A Case Study: a quantitative risk study by Office of Thrift Supervision (OTS)
  - Highlight: business risk concentration
  - Implications for managing the risks of the business processes of an enterprise
- My presentation does not represent the views of OTS

Outline of the Presentation

- A Case Study (work in progress): Office of Thrift Supervision
  - Data and reports: institutional framework
  - Valuation models
    - Interest rate model
    - Mortgage prepayment model
    - Credit risk model
  - Simulation (“stochastic on stochastic” models)
  - Analysis of simulation results
- Implications for ERM
  - Approaches to aggregating business risks
Office of Thrift Supervision

- Federal regulator of over 800 savings institutions or thrifts
- Monitors the risks on the balance sheet and the businesses
- Role of OTS examiners
- Ensure safety and soundness of the thrift industry
- Similar to the risk management of an enterprise with multiple businesses

Net Portfolio Value (NPV) Model

- A supervisory tool that identifies thrifts with excessive interest rate risks
  - A starting point for assessing the quality of interest rate risk management practices at individual thrifts
  - Identify outlier thrifts that need more supervisory attention
  - Identify systemic interest rate risk trends within the thrift industry
  - Designed to spot storm clouds on the horizon
- Fair valuation of all balance sheet items in disaggregated level using the CMR schedules
- Determine the market value of equity for each thrift
## Schedule CMR and IRR Report

- **CMR Filing Statistics (June 30, 2005)**
  - 821 OTS-regulated thrifts filed Schedule CMR
  - 58.5% of reports were from voluntary filers
  - 90.7% of institutions that are not required to file Schedule CMR do so voluntarily

- **Interest Rate Risk (IRR) Report**
  - Over 15 years of historical data

## Example of CMR /IRR Report

**Input data and Interest Rate Risk Report**

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-Year Mortgage Loans</td>
</tr>
<tr>
<td>30-Year Mortgage Securities</td>
</tr>
<tr>
<td>15-Year Mortgages and MBS</td>
</tr>
<tr>
<td>Balloon Mortgages and MBS</td>
</tr>
<tr>
<td>6 Month or Less Reset Frequency (Single-Family ARM)</td>
</tr>
<tr>
<td>7 Month to 2 Year Reset Frequency (Single-Family ARM)</td>
</tr>
<tr>
<td>2+ to 5 Year Reset Frequency (Single-Family ARM)</td>
</tr>
<tr>
<td>1 Month Reset Frequency (Single-Family ARM)</td>
</tr>
<tr>
<td>2 Month to 5 Year Reset Frequency (Single-Family ARM)</td>
</tr>
<tr>
<td>Adjustable-Rate, Balloons (Multifamily &amp; Nonresidential Mortgage)</td>
</tr>
<tr>
<td>Adjustable-Rate, Fully Amortizing (Multifamily &amp; Nonresidential Mortgage)</td>
</tr>
<tr>
<td>Fixed-Rate, Balloon (Multifamily &amp; Nonresidential Mortgage)</td>
</tr>
<tr>
<td>Fixed-Rate, Fully Amortizing (Multifamily &amp; Nonresidential Mortgage)</td>
</tr>
<tr>
<td>Adjustable-Rate (Construction &amp; Land Loan)</td>
</tr>
<tr>
<td>Fixed-Rate (Construction &amp; Land Loan)</td>
</tr>
<tr>
<td>Adjustable-Rate (Second Mortgage)</td>
</tr>
</tbody>
</table>

And More....
Interest Rate Model

- Generalized Ho-Lee model: n factor implied principal yield curve movements
  - Arbitrage-free calibrated to the Treasury curve
  - Implied mixed lognormal/normal model
  - Implied rate correlations
- Calibrated to the entire swaption surface
- Contrast with BGM (LIBOR, Market), String, Unspanned volatility models.

Estimated Implied Volatility Function:
Principal movements of the yield curve
Stochastic Movements of the Implied Volatility Functions:
Importance of implied correlations and distributions

Valuation Errors of the Generalized Ho-Lee Model:
Accuracy and stability of the model (Ho-Mudavanhu (2006))

Fig. 16 Comparison of the percentage absolute errors of the one factor and two factor models.
Research on Prepayment and Default Model

- Multinomial logit model
- FICO score
  - Impact on prepayments
  - Impact on the option adjusted spreads
- Multiple prepayment models
  - Hybrid ARMs
  - FRM
- Extension to mortgage loan valuation

Multinomial Prepayment/Default Model:
Specification of the correlation of prepayment and default risks

- CPR_{i,t} = \exp ( x(i, t)' \beta_p ) / A
  and
- CDR_{i,t} = \exp ( x(i, t)' \beta_d ) / A
- where A = 1 + \exp ( x(i, t)' \beta_p ) + \exp ( x(i, t)' \beta_d )
- x(i,t) independent variables: age, seasonality, refi function, FICO score
Prepayment/Default Model Results:
Preliminary results on fixed rate mortgages

- Refi and burnout effect
  - The model confirms the S curve behavior of refi.
  - The burnout effect is significant
- Slope of the yield curve
  - Higher the slope, greater is prepayment (positive)
- Seasoning effects
  - The results confirm the PSA model
  - The results show that the default rate peaks in 5 years
- FICO effect
  - For prepayment, the higher the FICO score, the more likely that the mortgagor prepays
  - In the default model, FICO score is significant
- Size: hot and cold money
  - Larger the origination size, hotter is the money
  - Larger the origination size, the higher is the default risk

Default Risk Modeling: Correlation

- Survival rate: derived from historical cumulative default experience for each rating cohort group
- Recovery rate: by seniority (historical)
- Correlation: by industry (historical)
- Standard deviation: concentration in each industry
- Default event: maturity structure
Default Correlation

- Gaussian and t-dependence copula model
- Input data:
  - Face value/portfolio
    - Loans
      - construction, consumer, commercial
    - Fixed income securities
  - Proportion in
    - Industry group
    - Maturities
    - Ratings

Scenario Generation:
Stochastic simulations of market and credit risks

- Quarterly reporting cycles
  - Time horizon: 3 months
  - Monthly reinvestments
- Antithetic Monte-Carlo simulation
- Same set of scenarios for all the thrifts
- Combined market and credit risks
- Default distribution and economic value over the horizon
Set of Risk Drivers:
Determination of the correlation matrix

- Market Risks
  - Yield curve movements
  - OAS spread risks
  - Equity risks
- Prepayment Risks
  - Coefficients of the prepayment model
- Credit Risks
  - Sector/industry groups
- Large singular correlation matrix
  - Decomposition to independent gaussian processes

Simulation Results

- Entire thrift population
- Market Value of Equity E: point estimate and distribution
- Risk Measures: Macro-Risk Management Perspective
  - VaR: 90% confidence level, 3 month horizon
  - Capital ratio = economic capital/total asset
  - Critical capital ratio = economic capital at 90% confidence level/total asset
Frequency Distribution of the Capital Ratio based on the Entire Population
Fair value analysis preliminary results December 2005

Impact of VaR at 90% Confidence Level
Identify the thrifts with lowered capital ratios
Risk Map

critical capital ratio = F (mortgage/E, deposit/E, loans/E)

Business Risk Concentration

Variations are driven by funding the mortgages by deposits
Business Models of Thrifts

Principal Components Analysis (preliminary)

<table>
<thead>
<tr>
<th></th>
<th>PC1</th>
<th>PC2</th>
<th>PC3</th>
</tr>
</thead>
<tbody>
<tr>
<td>mortgage/E</td>
<td>0.75</td>
<td>-0.64</td>
<td>0.13</td>
</tr>
<tr>
<td>Nonmort/E</td>
<td>0.02</td>
<td>0.23</td>
<td>0.97</td>
</tr>
<tr>
<td>Deposits/E</td>
<td>0.65</td>
<td>0.72</td>
<td>-0.19</td>
</tr>
</tbody>
</table>

- PC = principal components
- proportion of variations explained
- 78% (PC1), 17% (PC2), 5% (PC3)
- E = economic capital or equity

Relating the Risk Profiles to the Business Models:

Variations along PC1 vs Critical Capital

preliminary results

![Graph showing mortgage leverage vs critical capital level](image)
Implications of the OTS Case Study

- Dramatic change in the thrifts’ business model
  - Traditional, complex, wholesale, specialty banks
- Concentration of business risks in the banking system
  - Correlation of credit risk and market risk
  - Correlation of business risks: home price collapse, earthquakes, margin calls
- Implications of macroeconomics
  - What are the adverse scenarios for the banking system? Price level, rate level, liquidity level. Inter-relations of risks

Implications of the Case Study for ERM

- An enterprise is a portfolio of businesses, defined in terms of business processes, not only as corporate entities
- ERM should not aggregate the balance sheet risks only
- ERM should consider the correlation of business risks of the business processes
Summary: Aspects of Risk Aggregation

- Implied correlations of interest rates in valuation - interest rate models
- Default risk and product risks are correlated - prepayment models
- Credit risk and interest rate risk correlation - copula function
- Business risks and market/credit risks - business model

Principle Based Approach

- Calibration to the market prices
  - Law of one price – arbitrage free
- Prospective and retrospective analysis using a quarterly cycle
- Consistency across business units
- Comprehensive aggregation of risks
Conclusions

- Correlations of risk sources in valuation and simulations: new research results
- Business risk should be considered a distinct risk driver
- Metrics of risks for ERM should be taken into consideration – Correlation of risks, integrating risk measurement – risk aggregation is important
- OTS quantitative risk study highlights many of these issues

References

- Ho and Lee (2005) “Multifactor interest rate model”
- Papers available at www.thomasho.com
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