Measuring Financial Relationships

Mark D. Flood
Office of Financial Research

Institute for Pure and Applied Mathematics (IPAM)
Workshop on Forensic Analysis of Financial Data

Views expressed in this presentation are those of the speaker(s) and not necessarily of the Office of Financial Research.
Views and opinions expressed are those of the speaker and do not necessarily represent official OFR positions or policy.
Joint Work

Network Measurement
Mila Getmansky Sherman
U. Massachusetts
Ayeh Bandeh-Ahmadi
Office of Financial Research

Financial Contracts as Automata
Oliver Goodenough
Vermont Law School and OFR
Why Does It Matter?

“4-L” Club – Billio, Getmansky, Lo and Pellizon (2012):

Leverage

Losses

Linkages

Liquidity

Image source: OFR analysis
Traditional Measurement

**Firm-level financial statements**

- Highly standardized
  - FASB
  - GAAP
  - Basel capital rules

**Backward looking**

- Historical/fair value
- Monovalent

**Market transaction information**

**Pre-trade transparency**

- Quotes and spreads
- Limit orders

**Post-trade transparency**

- Transaction prices
- Volumes
Measuring the “Physical” Network

Direct measurement matters


Image source: Brunetti, Harris, Mankad, and Michailidis (2015)
Non-random Networks: Core-periphery Topology

Strategic network formation

• Counterparty graphs are non-random
  – Simple Erdös-Rényi is inadequate
• Core-periphery topology, for example
  – Capitalization requirements
  – Dealer monopoly unstable
  – Conflict-of-interest rules

Regulatory constraints on edge formation

• Chartering – permissible activities
• Volcker Rule
• SEC Rule 2a-7 for money funds

Endogenous forces

• Investment mandates and “objectives”
  – Leverage limits, use of derivatives, etc.
• Risk reduction procedures
  – Netting and novation

Money funds -- seeking yields and seeking safety in 2011

Image source: SEC N-MFP, OFR analysis
Ownership Hierarchies

- Directed acyclic graph
- Definition of “ownership”
- Evolving over time
- Wells Fargo BHC (pruned), between 2006 and 2010:
  - New since 2006
  - Gone since 2006
  - Always present

Some statistics:
- Nodes (pruned): 478
- Diameter (dir.): 9
- Avg. path length: 2.233
- Modularity: 0.811

Image source: FFIEC (2015), OFR analysis
Accumulating Concentrations: CDX.NA.IG.9

- **Net positions**

- **Absolute value of positions**

*Image source: OFR analysis*
Net Positions in CDX.NA.IG.9

Net positions aggregated by counterparty types

- Multiple CDS maturities; trading on Jan. 1, 2010 – Aug. 8, 2014
Gross Positions in CDX.NA.IG.9

Gross positions aggregated by counterparty types

- Multiple CDS maturities
- Jan. 1, 2010 – Aug. 8, 2014

Image source: OFR analysis
Focus on Contracts

Contracts

- Instruments
- Legal Entities
- Relationships
- Positions & Portfolios
- Transactions
- Messages

Image source: OFR analysis
A “Toy” Loan Agreement

Simple two-page loan contract

1. The Loan: $1000, June 1, 2014
2. Repayment:
   • Payment 1, due June 1, 2015: $550
   • Payment 2, due June 1, 2016: $525
3. Representations and Warranties
4. Covenants
5. Events of Default:
   • Borrower fails to make timely payment
   • Reps or warranties prove untrue
   • Borrower fails any covenants
   • Borrower files for bankruptcy
6. Acceleration on Default
7. Choice of Law
8. Amendments and Waivers
9. Courts and Litigation
10. Time of the Essence; No Pre-Payment
11. Notices

Image source: OFR analysis

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Deterministic Finite Automaton (DFA)

• A deterministic finite automaton (DFA) is defined by a 5-tuple:
  – Finite set of states \( Q \)
  – Finite set of input symbols (information/events) called the alphabet \( \Sigma \)
  – Transition function \( \delta : Q \times \Sigma \rightarrow Q \)
  – Start state \( q_0 \in Q \)
  – Set of accept (end) states \( F \subseteq Q \)

• Three representations (at least):
  – Lists (of \( Q, \Sigma \) and \( \delta \))
  – Graphical (depiction of states and transitions among them)
  – Regular expression (shorthand grammar of acceptable event sequences)
**Representation II: Tabular**

<table>
<thead>
<tr>
<th>State Space (27)</th>
<th>Event Alphabet (20)</th>
<th>Transitions (45)</th>
</tr>
</thead>
</table>

**Q**

<table>
<thead>
<tr>
<th>State</th>
<th>Label</th>
<th>Natural Language Consequences and Correlations (*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start</td>
<td></td>
<td>Contracts fully specified, key information (grant, dates, notice addresses and procedures, choice of law and dispute process delivered)</td>
</tr>
<tr>
<td>Active contract</td>
<td></td>
<td>Contract is fully signed/executed</td>
</tr>
<tr>
<td>Principal requested</td>
<td></td>
<td>Borrower has requested and agrees $10,000</td>
</tr>
<tr>
<td>End</td>
<td></td>
<td>Loan is no longer active</td>
</tr>
</tbody>
</table>

**Σ**

<table>
<thead>
<tr>
<th>ID</th>
<th>Label</th>
<th>Natural language event specification</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Contract signed</td>
<td>Contract is signed and all parties agree</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>1 year passes since last event</td>
<td>Payment due on June 1, 2014</td>
<td>A.3</td>
</tr>
<tr>
<td>C</td>
<td>Money requested</td>
<td>Borrower gives request for loan of $10,000</td>
<td>A.1</td>
</tr>
<tr>
<td>D</td>
<td>Lien</td>
<td>A legal action is brought to enforce, interpret or otherwise deal with the agreement in the state courts of the State of New York located in New York County</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Notice of completion of limitations on debt obligations in New York</td>
<td>Notice of completion of limitations on debt obligations in New York</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>Principal advanced</td>
<td>Lender advances $1,000 no later than June 2, 2014</td>
<td>A.2</td>
</tr>
<tr>
<td>G</td>
<td>Loan</td>
<td>Payment 1 due on June 1, 2015</td>
<td>2.0(3)</td>
</tr>
<tr>
<td>H</td>
<td>Repayment</td>
<td>The borrower’s assets exceed its liabilities as determined under an application of the Fair’s rule of accounting</td>
<td>3.5(b)</td>
</tr>
<tr>
<td>I</td>
<td>Covenant</td>
<td>The borrower fails to make a timely payment of an amount of state or federal tax</td>
<td>4.5(c)</td>
</tr>
<tr>
<td>J</td>
<td>Bankruptcy</td>
<td>The borrower fails for bankruptcy or insolvency under any applicable federal or state law</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>Notice</td>
<td>Notice given to borrower of failure to make timely payment of an amount due under the agreement</td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>Notice given of general default</td>
<td>Notice given to borrower of a failure to make timely payment of an amount due under the agreement</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>Payment default cured</td>
<td>5.5(c)</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>General default cured</td>
<td>A non-payment related event of default is cured</td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>2 Days Pass Since Last Event</td>
<td>Two days since last event occurrence</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>June 1, 2014 Payment</td>
<td>Payment 2 is due on June 1, 2014</td>
<td></td>
</tr>
<tr>
<td>Q</td>
<td>Payment made</td>
<td>Payment made, but no payments made of any given amount</td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>Payment made</td>
<td>Payment made, but no payments made of any given amount</td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>Terminate</td>
<td>Contract is terminated because of modification or termination by mutual agreement of the parties</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>δ</th>
<th>Initial State</th>
<th>Event</th>
<th>Resulting State</th>
</tr>
</thead>
<tbody>
<tr>
<td>δ₁</td>
<td>P₁, Q₁</td>
<td>R₁</td>
<td>P₁, Q₁, δ₁</td>
</tr>
<tr>
<td>δ₂</td>
<td>P₁, Q₁</td>
<td>R₂</td>
<td>P₁, Q₁, δ₂</td>
</tr>
<tr>
<td>δ₃</td>
<td>P₁, Q₁</td>
<td>R₃</td>
<td>P₁, Q₁, δ₃</td>
</tr>
</tbody>
</table>

**Image source**: OFR analysis
DFA as a chain of event and consequence:

- Start state ($q_0$) at the top
- Terminal states (3) at bottom
- “Happy” or intended path traced in green
- More “interesting” ramifications traced in black
Representation III: Regular Expression

Regular expressions list the “acceptable” event sequences under the DFA

• Uses a compact shorthand notation
• Equivalent (without labels) to the tabular and graphical representations
• Natural measure of complexity (i.e., length of the regex)

\[ A(B|CB[ED]) | \]

\[ ACF (G (BK) ?) QPR | \]

\[ ACF ([HIJ]LN) *(GBK|[HIJ]L)O(S|B[DES]) | \]

\[ ACF (G (BK) ?) Q ([HIJ]LN) *(PBK|[HIJ]L)O(R|B[RED]) \]

\[ \text{Rapid demise} \]

\[ \text{Happy path} \]

\[ \text{Unhappy 1} \]

\[ \text{Unhappy 2} \]
Implications – Complexity

• **Basic Results on Complexity**
  – DFAs enforce the Markov (or Myhill-Nerode) property – *state is “memoryless”*
    • The DFA “lives in the moment” – all transitions are one-step-ahead actions
  – Computational complexity is manageable:
    • Constrained by the Myhill-Nerode condition
    • Measurable by the descriptional complexity of the regular expression
  – The law appears to have evolved this constraint organically
    • Sorcerer’s Apprentice problem

• **Assessing Complexity**
  – The complexity of actual contracts is (in theory) rigorously measurable
  – The computational “inefficiency” of a contract is measurable:
    • Measure the contract’s actual complexity, $C$
    • Reduce the contract’s DFA to its theoretical minimum and measure that complexity, $C^*$
    • The difference, $\Delta C = (C - C^*)$, is a measure of “unnecessary” complexity
Galline Ontogeny Feedback Loop

**Economic and policy forces**
- Privacy and confidentiality
- Data management costs
- Incentive problems

**Co-evolution of analytics and data requirements**
- Data requirements depend on the analytical models the data will feed.
- Analytical models evolve in response to results obtained from available data.

**Avoiding data “stovepipes” via data abstraction**
- Policy-mechanism separation
- Role-and-context-based access control

Fundamental Rule of Data Collection

Endogenous Myopia
Firms will not disclose their positions
Myopia: firms’ visibility distance \( \leq 1 \)
→ Role for public supervision

State-dependent Data Requirements
Supervisory needs increase under:
- Crisis monitoring
- Failure resolution
- Forensic investigation

Shneiderman’s Visualization Mantra
- Overview first
- Zoom and filter
- Details on demand

System-wide Data Collection

Requires

Data Standards
Gratitude

Thanks!