Designing an expert knowledge-based Systemic Importance Index for financial institutions

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Disclaimer: The opinions and statements are the sole responsibility of the authors and do not necessarily represent neither those of Banco de la República nor of its Board of Directors. Results are illustrative; they may not be used to infer credit quality or to make any type of assessment for any financial institution. Authors are grateful to the officers and technical staff involved in the design of the expert knowledge base. Discussions with Alejandro Reveiz regarding the design of the model were essential for its implementation. Valuable comments and suggestions were provided by Joaquín Bernal, Ernesto Aguirre, Dairo Estrada, Orlando Chipatecua, Freddy Cepeda, Fabio Ortega and Constanza Martínez. Balance sheet data was processed with assistance from Jorge Cely and Linda Mondragón.
The interesting question is not whether or not risk will crystallize, as in one form or another risks crystallize every day. Rather, the important question is whether, in the event of nasty shocks, our capital markets can absorb them or whether they have developed characteristics which may, as some suggest, leave them vulnerable.

Paul Tucker (2005)
Executive Director for Markets and member of the Monetary Policy Committee
Bank of England

In this sense, the main ideas behind the paper are:

- On average the financial stability and payments system safety may be “guaranteed”, but not when confronted with a systemically important participant failing.

- Financial authorities should be prepared to confront a non-average but extreme threat to financial stability by a systemically important participant.

- The big challenge: to assess and identify systemic importance as the “sum” of size, connectedness and non-substitutability in a comprehensive but intuitive manner.
I. The challenge of identifying systemic importance

II. Modeling systemic importance with a fuzzy logic inference model

III. Main results

IV. Final remarks
I. The challenge of identifying systemic importance

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The challenge of identifying systemic importance

Some lessons from the crisis:

- Systemic financial risk is not restricted to banks. *(French et al., 2010)*

- Financial stability may not only be endangered by large banking institutions *(too-big-to-fail)*, but by heavily interconnected financial institutions *(too-connected-to-fail)*.

- Connectedness may be intricate to assess, with regulators and central banks currently lacking the resources to carry out this kind of analysis. *(Clark, 2010)*

- Systemic regulators need a new infrastructure to collect and analyze adequate information from large and systemically important financial institutions. *(French et al. 2010)*
In their 2009 document, IMF, BIS & FSB stressed the importance of assessing and identifying financial institutions systemic risk.

They also highlighted that it is necessary to acknowledge that...

- Three key criteria that are helpful in assessing and identifying the systemic importance of financial institutions are: **size, connectedness and substitutability**.
- A high degree of judgment founded in a **detailed knowledge of the functioning of the financial system** is required in any assessment of systemic importance.
- Assessing the systemic importance of an institution **does not lend itself to binary outcomes**.
- The assessment of systemic importance **cannot be based simply on quantitative methods**.

BIS (2011) introduces a model for systemic risk assessment. However...

- The four aforementioned issues are not considered.
- It is limited to banking institutions.
The issues highlighted by IMF, BIS & FSB (2009) result in three main challenges:

- How to assess complex and dissimilar concepts? (size, connectedness, substitutability)
- How to define a threshold for too-big, -connected, -non-substitutable? For systemically important?
- How to involve expert knowledge in defining what a systemically important financial institution is?

We need a model or system capable of (i) dealing with complex concepts; (ii) with a non-binary framework; (iii) that captures and mimicks human reasoning.

How does Engineering tackle such type of challenges? Fuzzy logic
The challenge of identifying systemic importance

Fuzzy Logic applications are everywhere...

Financial

• Credit risk modeling
• Fraud detection in insurance
• Bond credit ratings
• Operational risk modeling
• Portfolio optimization

Non-Financial

• Auto industry (ABS braking)
• Aeronautical radars
• Medicine
• Heating control
• Home appliances
The challenge of identifying systemic importance

How to assess complex and dissimilar concepts? (size, connectedness, non-substitutability)

How to define a threshold for too-big, -connected, -non-substitutable? For systemically important?

How to involve expert knowledge in defining what a systemically important financial institution is?

Designing indexes for size, connectedness, non-substitutability and systemic importance

Designing intuitive categories within each index (very low, low, medium...)

Defining how the indexes and their categories interrelate and how they result in different levels of systemic importance

Quantitative
Sources:
• Balance sheet
• LVPS & other infrastructures

Qualitative
(Depends on expert knowledge)

It is necessary to capture expert knowledge in order to provide the Systemic Important Index with the “human” ability to identify systemically important financial institutions based on complex and ambiguous indexes for size, connectedness and non-substitutability.
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Designing the indexes

- Each index consists of a typical standardization of the variable; the highest number is assigned the maximum index value (10) and the rest is assigned an index value by means of linear interpolation.
- It is important to emphasize that the assessment obtained with the Index is not absolute, but relative to the most systemically important institution.

<table>
<thead>
<tr>
<th>Key indicators</th>
<th>Description</th>
<th>Source / Estimation</th>
<th>Rationale (When facing a failing or near-failing institution)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[A] Volume of deposits and money market borrowing</td>
<td>Face value of liabilities a financial institution would fail to pay to the public and to other participants of the financial system in the short run.</td>
<td>Balance sheet data provided by the Banking Superintendence of Colombia.</td>
<td>... the larger the deposits and money market borrowing...</td>
</tr>
<tr>
<td>[B] Volume of financial assets under management</td>
<td>Market value of proprietary assets that may be sold in order to obtain liquidity in the short run, and the volume of assets from third parties which could be compromised or mismanaged in the short run in case of a failure or near failure.</td>
<td>Balance sheet data provided by the Banking Superintendence of Colombia.</td>
<td>... the larger the volume of financial assets under management...</td>
</tr>
<tr>
<td>[C] Contribution to the payment system</td>
<td>Contribution to the total payments of the large-value payment system, weighted by the contribution to the total connections of the large-value payment system (CUD).</td>
<td>Large-value payments system statistics provided by Banco de la República (CUD).</td>
<td>... the larger the volume of payments and the number of connections...</td>
</tr>
<tr>
<td>[D] Betweenness centrality</td>
<td>Degree of involvement of a participant in the indirect-connection of all other participants within the large-value payment system (CUD).</td>
<td>Estimated as the change in the average number of links necessary for each participant to be connected to all other participants; if removing an institution results in a major (minor or nil) increase in the average number of links all institutions require to remain connected as before, the removed institution is to be considered as of low (high) substitutability. Data provided by CUD.</td>
<td>... the larger the betweenness centrality...</td>
</tr>
</tbody>
</table>

Table 1: Systemic importance key indicators

Source: authors’ design

Network Theory (on LVPS data)
Modeling systemic importance with a fuzzy logic inference model

- Designing indexes for size, connectedness, non-substitutability and systemic importance
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Quantitative
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Source:
- Expert knowledge
In contrast to ordinary sets, Lofti A. Zadeh (1965) acknowledged the fact that in reality there are elements characterized by membership functions which are not discrete, but continuous, where different degrees of membership exist between yes or no.

In this sense, a simple reality check:

- Are we 100% sure that bank B is not large?
- Are we 100% sure that bank C is significantly larger than bank B?

Despite size is a countable and objective metric, deciding whether an institution is large (or not) is subjective, and should not be regarded in binary terms… .. but as pertaining to some degree of truth.
**Designing intuitive categories**

(\textbf{Fuzzification})

The conversion of a crisp quantity to the appropriate fuzzy sets through the use of continuous membership functions, is known as fuzzification.

**Size, connectedness and non-substitutability as fuzzy variables (inputs)**

- The number of input membership functions should allow a detailed characterization and differentiation of several degrees of size, connectedness and substitutability.
- The number of input membership functions should be limited in order to avoid unnecessary complexity for the model, and to facilitate deconstructing experts' knowledge.
- Complexity of the model: \((\#\text{membership functions})^{(\#\text{criteria})} = 3^4 = 81\)

**Systemic Importance as a fuzzy variable (output)**

- The number of output membership functions should allow a detailed characterization and differentiation of what a systemically important institution is.
- The number of output membership functions should be limited in order to avoid unnecessary complexity for the model, and to facilitate deconstructing experts' knowledge.

The conversion of a crisp quantity to the appropriate fuzzy sets through the use of continuous membership functions, is known as fuzzification.
Modeling systemic importance with a fuzzy logic inference model

- Designing indexes for size, connectedness, non-substitutability and systemic importance
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Quantitative Sources:
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Qualitative Source:
- Expert knowledge
Designing how inputs and outputs relate (Inference rules)

- Inference rules: knowledge base that contains general knowledge pertaining to a problem domain; connects antecedents with consequences, premises with conclusions, or conditions with actions.

if [A] is HIGH; [B] is HIGH; [C] is HIGH; [D] is HIGH → [SYSTEMIC IMPORTANCE] is VERY HIGH

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<tbody>
<tr>
<td>1</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Systemic Importance Level</td>
</tr>
<tr>
<td>2</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Systemic Importance Level</td>
</tr>
<tr>
<td>3</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Systemic Importance Level</td>
</tr>
<tr>
<td>4</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>Systemic Importance Level</td>
</tr>
<tr>
<td>5</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Systemic Importance Level</td>
</tr>
<tr>
<td>78</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
<td>Medium</td>
<td>Systemic Importance Level</td>
</tr>
<tr>
<td>79</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>Systemic Importance Level</td>
</tr>
<tr>
<td>80</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
<td>Systemic Importance Level</td>
</tr>
<tr>
<td>81</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Systemic Importance Level</td>
</tr>
</tbody>
</table>

(#membership functions)(#criteria) = 3^4 = 81
Designing how inputs and outputs relate (inference rules)

Expert knowledge is captured with a survey...

- A survey containing the 81 propositions was answered by experts (lending-of-last-retort, financial stability, payment systems) within the central bank. Answers consolidated (mode of the answers) + consistency check.
- It is important to highlight to the experts that...
  - They must answer according to their experience and knowledge within the local market, with Colombian financial market’s instruments and regulatory framework in mind.
  - Their answers are confidential and won’t be disclosed individually.
- The survey included a clear description of concepts; several group and individual sessions of questions & answers to ensure homogeneity of concepts.
- The accompanying description of concepts stressed the importance of non-linearity of the criteria (e.g. non-substitutability’s importance increases with connectivity).
- The survey will be answered by the financial supervisor and the deposit guarantee fund.
MODELING SYSTEMIC IMPORTANCE WITH A FUZZY LOGIC INFERENCE MODEL

FUZZY LOGIC INFERENCE SYSTEM

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**Answers to the Survey (7 Experts)**

**Symmetric distribution**

- Traditional (linear) weighting results in most of the combinations yielding MEDIUM systemic importance, and only one of VERY HIGH systemic importance.

**Skewed distribution**

- Systemic importance arising from merging two financial institutions is different (i.e. expectedly higher) than the mere weighted sum of their systemic importance!
- “Anti-diversification” effect in place?

**Very High category**

- Unlike simple weighting schemes, experts consider that more than one proposition (i.e. 4*HIGH) results in VERY HIGH systemic importance.
The knowledge base (from the survey)

The knowledge base is “observable”

- Surfaces allow for observing the rules at work (i.e. *ceteris paribus*, how two criteria interrelate and result in systemic importance)
- Surfaces also allow to detect inconsistent answers to the survey; surfaces should be intuitive and continuous (no jumps).
The systemic importance index

- The types which concentrate most systemic importance in the Colombian financial market are commercial banks (CBs) and brokerage firms (BFs), as in León et al. (2011) and Machado et al. (2010).
- CBs and BFs are the only type of institutions pertaining to some degree to the HIGH and VERY HIGH categories (i.e. membership functions).

- Two broker-dealer firms are systemically more important than the average banking firm!
- Everyone knew it, but there was no assessment to prove it.
The systemic importance index

Where does the systemic importance come from for each institution?

[A] Volume of deposits and money market borrowing

[B] Volume of financial assets under management

[C] Contribution to the payment system

[D] Betweenness centrality

These two broker-dealer firms are too-connected-to-fail institutions.
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Final remarks

• The proposed methodology allowed for:

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  How to involve expert knowledge in defining what a systemically important financial institution is?
Final remarks

• Results obtained by the proposed methodology are straightforward and grant financial authorities with the ability to acquire a comprehensive relative assessment of each financial institution’s systemic importance.

• This may serve the purpose of assisting financial authorities in focusing their attention and resources – the intensity of oversight, supervision and regulation—where the systemic severity resulting from a financial institution failing or near-failing is estimated to be the greatest.

• Results confirm that experts already regard the too-connected-to-fail criteria as important as the too-big-to-fail criteria, which concurs with developments after the most recent episode of global financial crisis.

• In a forthcoming paper (León & Murcia, 2012) the results are contrasted (and verified) with a purely quantitative approach (Principal Component Analysis).
Final remarks

- Challenges ahead
  - How to implement the methodology for financial infrastructures?
  - How to capture financial conglomerates as a relevant variable?
  - Contrasting the results from the central bank’s survey with the results from other authorities pertaining to the financial sector safety net.
  - Including additional criteria is costly (burdensome)… how to make the survey easier?