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

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Available at http://www.banrep.gov.co/docum/ftp/borra669.pdf

[T]he interesting question is not whether or not risk will crystallize, as in one form or another risks crystallize every day. Rather, <u>the important question is whether, in the event of nasty shocks, our capital markets can absorb them</u> or whether they have developed characteristics which may, as some suggest, leave them vulnerable.

<div align="right">
Paul Tucker (2005)
Executive Director for Markets and member of the Monetary Policy Committee
Bank of England
</div>

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

II. MODELING SYSTEMIC IMPORTANCE WITH A FUZZY LOGIC INFERENCE MODEL

III. MAIN RESULTS

IV. FINAL REMARKS

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)*
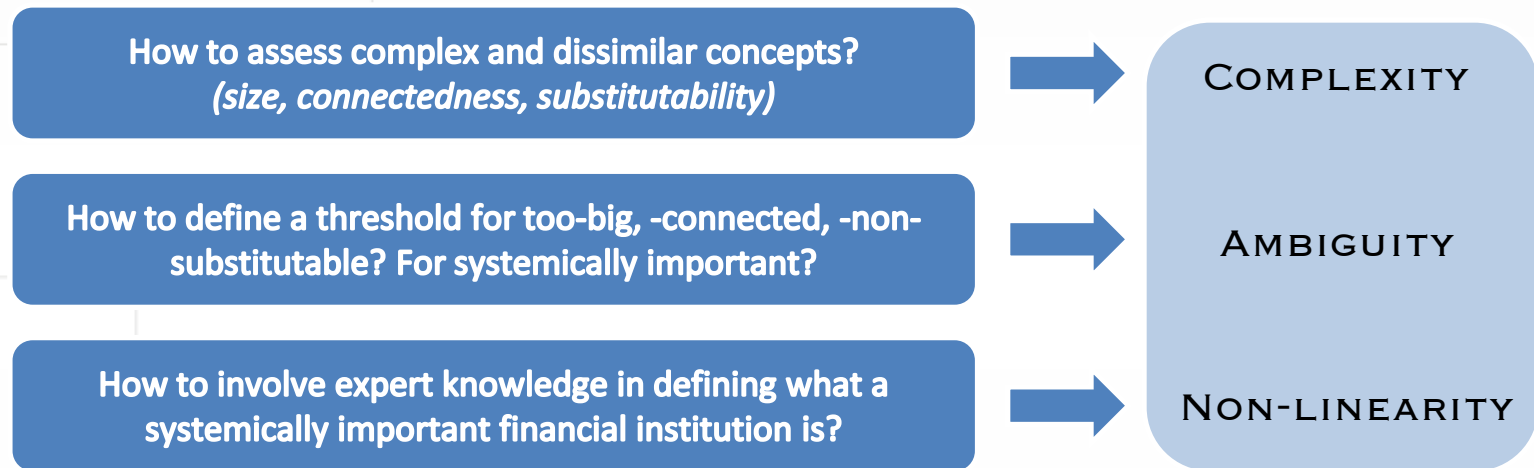
The challenge of identifying systemic importance

- 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 challenge of identifying systemic importance

- The issues highlighted by IMF, BIS & FSB (2009) result in three main challenges:

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

- 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...
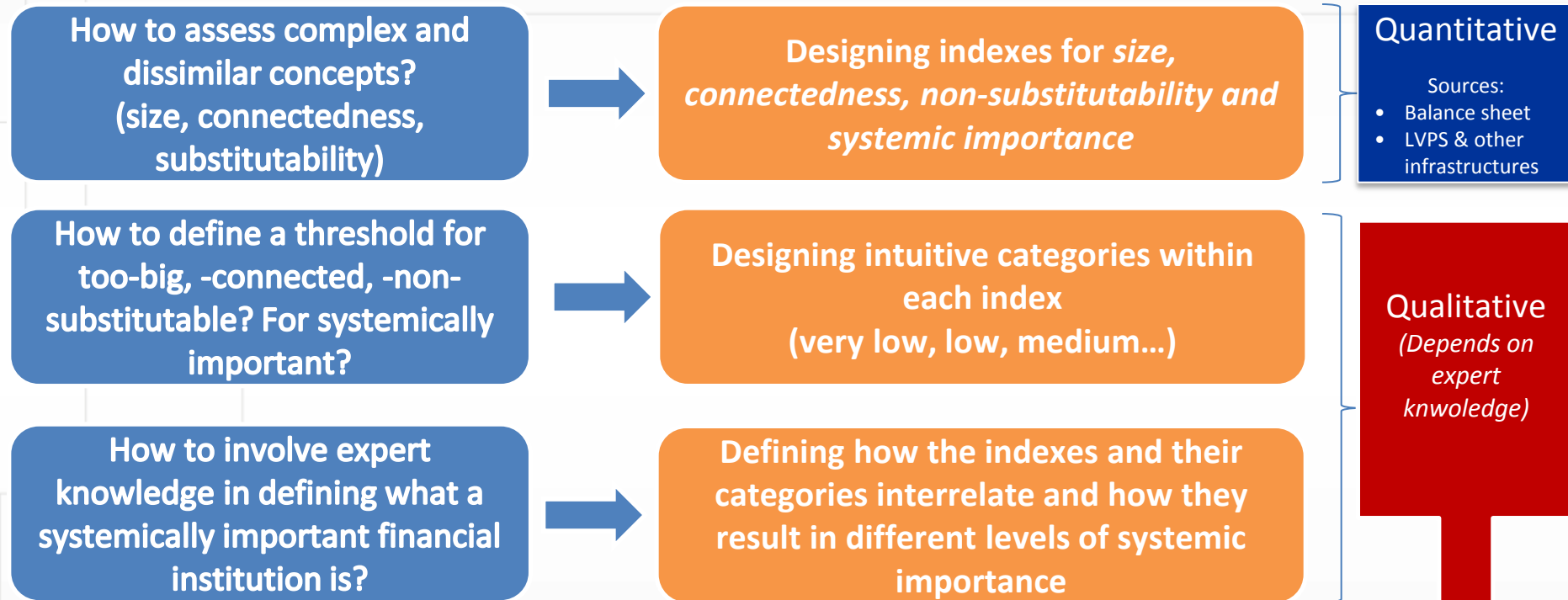
Financial

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

Quantitative
Sources:
- Balance sheet
- LVPS & other infrastructures

How to define a threshold for too-big, -connected, -non-substitutable? For systemically important? → **Designing intuitive categories within each index (very low, low, medium...)**

Qualitative
(Depends on expert knwoledge)

How to involve expert knowledge in defining what a systemically important financial institution is? → **Defining how the indexes and their categories interrelate and how they result in different levels of systemic importance**

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-substitutuability.

Modeling systemic importance with a fuzzy logic inference model
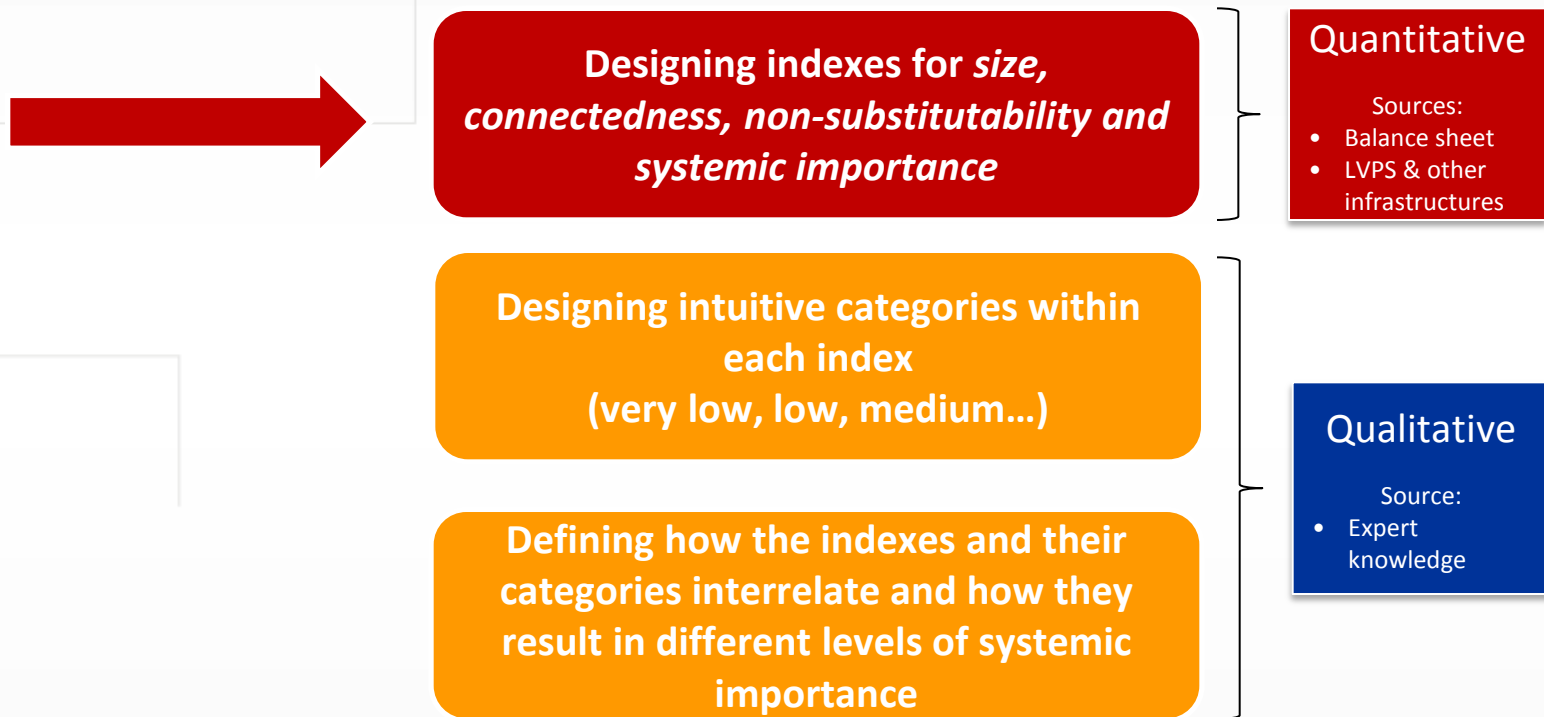
Designing indexes for *size, connectedness, non-substitutability and systemic importance*

Quantitative

Sources:
- Balance sheet
- LVPS & other infrastructures

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

Qualitative

Source:
- Expert knowledge

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

Designing the indexes

- Each index consist 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 1
Systemic importance key indicators

Key indicators	Description	Source / Estimation	Rationale (When facing a failing or near failing institution…)
[A] Volume of deposits and money market borrowing	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.	Balance sheet data provided by the Banking Superintendence of Colombia.	… the larger the deposits and money market borrowing… • the larger the potential loss in confidence of the public. • the larger the potential impact on other institutions liquidity and solvency. • the larger the potential monetary impact of central bank's liquidity supply to affected financial institutions.
[B] Volume of financial assets under management	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.	Balance sheet data provided by the Banking Superintendence of Colombia.	… the larger the volume of financial assets under management… • the larger the potential impact on liquidity and solvency of other financial institutions via "liquidity spirals". • the larger the potential impact on the real economy via market prices and portfolios' mismanagement. • the larger the potential monetary impact of central bank's liquidity supply to affected financial institutions.
[C] Contribution to the payment system	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).	Large-value payments system statistics provided by Banco de la República (CUD).	… the larger the volume of payments and the number of connections… • the larger the number of potential institutions affected and the severity of the affectedness. • the larger the potential disruption in the money, capital and exchange markets. • the larger the potential monetary impact of central bank's liquidity supply to affected financial institutions.
[D] *Betweenness centrality*	Degree of involvement of a participant in the –indirect- connection of all other participants within the large-value payment system (CUD).	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.	… the larger the betweenness centrality… • the higher the potential efficiency and safety losses for the system. • the larger the potential disruption in the money, capital and exchange markets.

Source: authors' design

Too-big-to-fail

Too-connected-to-fail

Network Theory (on LVPS data)

Counterparty Risk

Fire-sale Risk

Liquidity Risk

Single-point-of-failure Risk

Modeling systemic importance with a fuzzy logic inference model

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

Quantitative

Sources:
- Balance sheet
- LVPS & other infrastructures

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

Qualitative

Source:
- Expert knowledge

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

Designing intuitive categories (fuzzification)

- 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.

Assets' size as an ordinary and a fuzzy variable
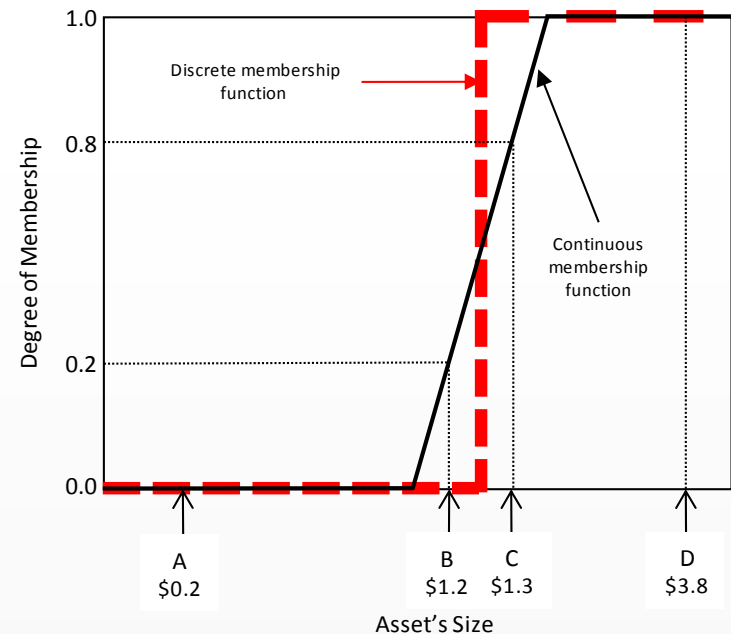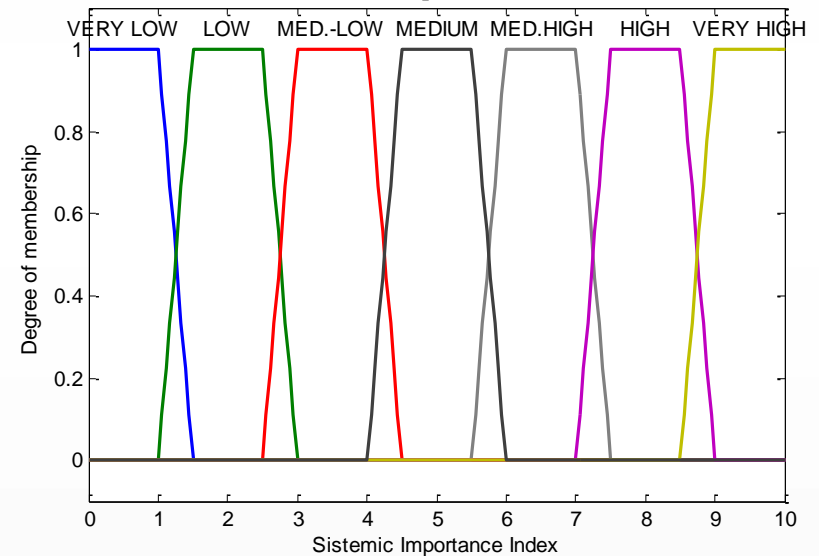
Designing intuitive categories
(fuzzification)

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)
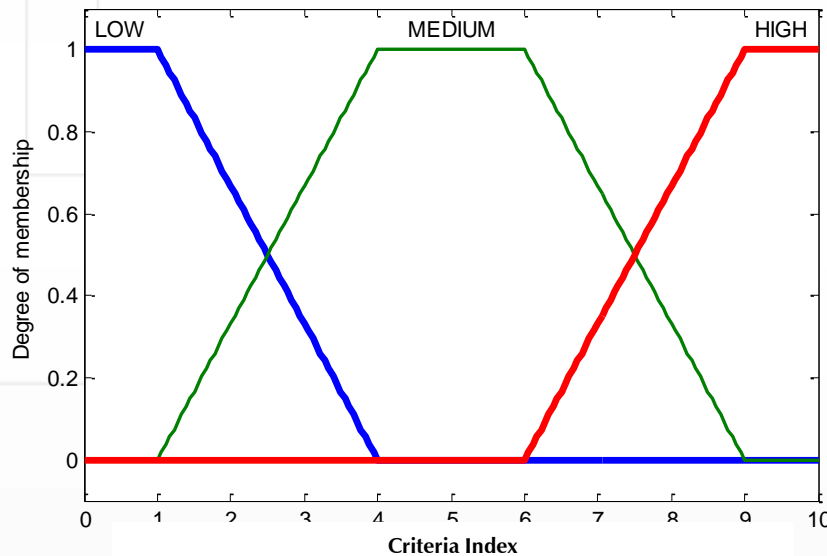
Systemic Importance as a fuzzy variable (output)

- The number of input membership functions should allow a detailed characterization and differentiation of several degrees of size, connectedness and subtitutability.
- 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:

$$(\#\text{membership functions})^{(\# \text{ criteria})} = 3^4 = 81$$

- 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.

Modeling systemic importance with a fuzzy logic inference model

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

Quantitative

Sources:
- Balance sheet
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**Designing intuitive categories within each index
(very low, low, medium…)**

Qualitative

Source:
- Expert knowledge

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

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*

#	[A] Volume Deposits and Interbank Borrowing	[B] Volume of Financial Assets Under Management	[C] Contribution to the Payments System	[D] Betweenness Centrality	Systemic Importance Level (Select a single proposition)						
					Very Low	Low	Med.-Low	Medium	Med.-High	High	Very High
1	High	High	High	High							✔
2	High	High	High	Low							
3	High	High	High	Medium							
4	High	High	Low	High							
5	High	High	Low	Low							
⋮											
78	Medium	Medium	Low	Medium							
79	Medium	Medium	Medium	High							
80	Medium	Medium	Medium	Low							
81	Medium	Medium	Medium	Medium							

$$(\#\text{membership functions})^{(\#\text{ criteria})} = 3^4 = 81$$

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 wont 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

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

Quantitative

Sources:
- Balance sheet
- LVPS & other infrastructures

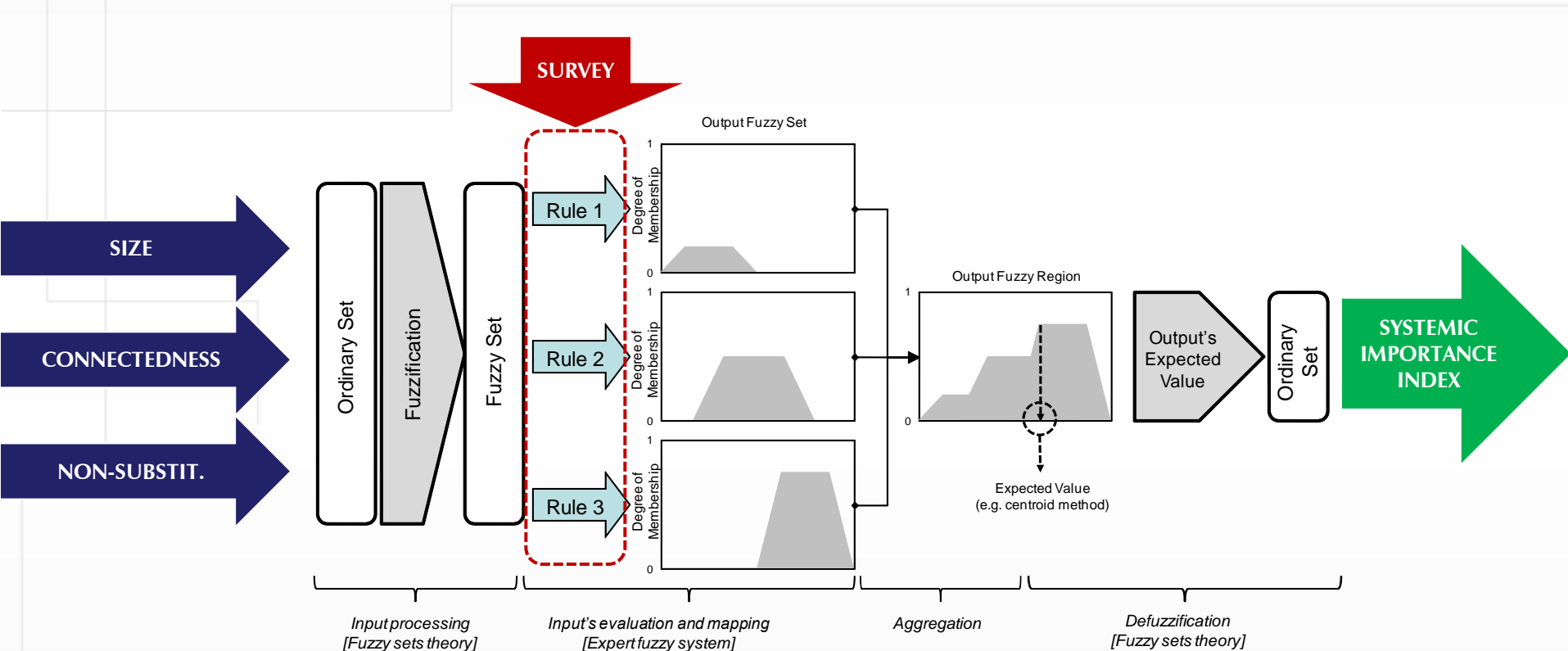**Designing intuitive categories within each index (very low, low, medium…)**

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

Qualitative

Source:
- Expert knowledge

Modeling systemic importance with a fuzzy logic inference model

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?
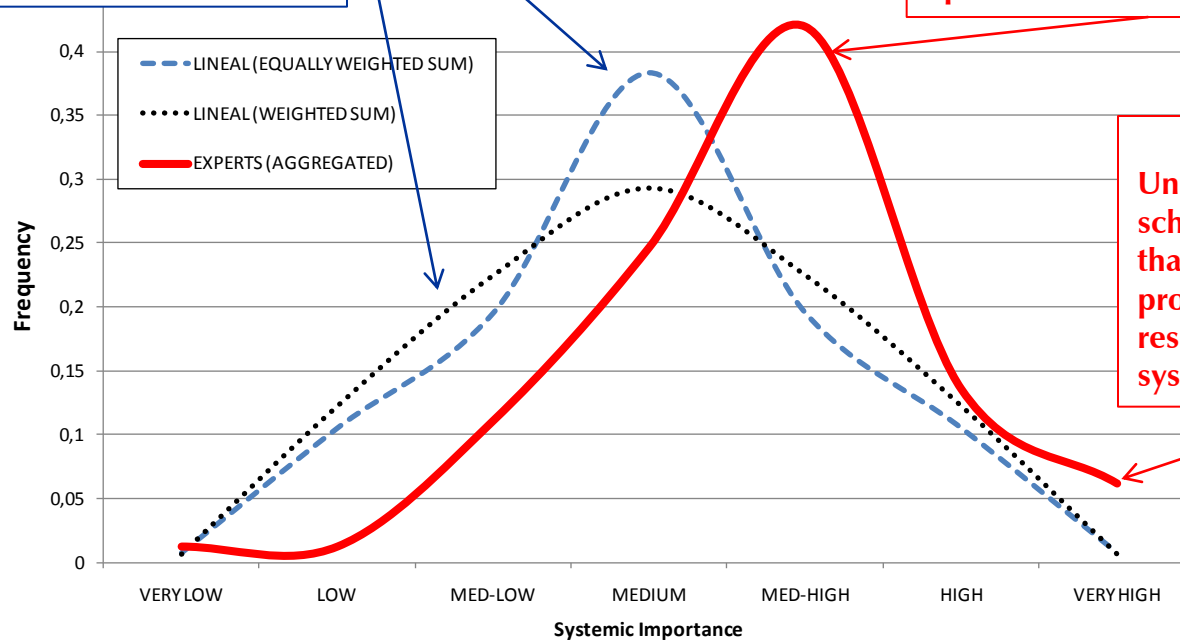
VERY HIGH category
Unlike simple weighting schemes, experts consider that more than one proposition (i.e. 4*HIGH) results in VERY HIGH systemic importance.

Legend:
- - - LINEAL (EQUALLY WEIGHTED SUM)
- - - - LINEAL (WEIGHTED SUM)
——— EXPERTS (AGGREGATED)

Y-axis: Frequency (0, 0,05, 0,1, 0,15, 0,2, 0,25, 0,3, 0,35, 0,4)

X-axis: Systemic Importance (VERY LOW, LOW, MED-LOW, MEDIUM, MED-HIGH, HIGH, VERY HIGH)

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).
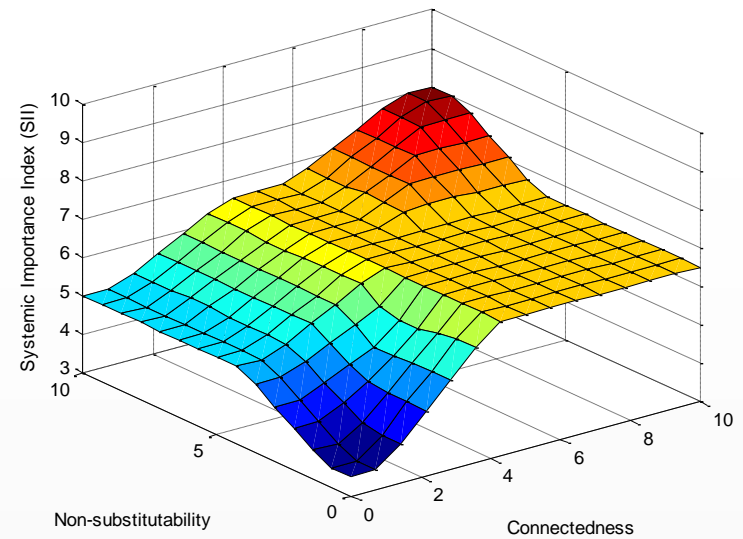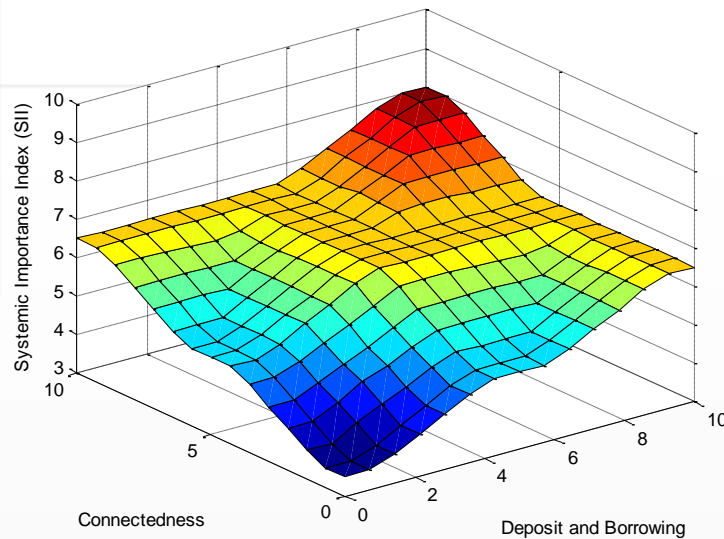
The systemic importance index

- 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).
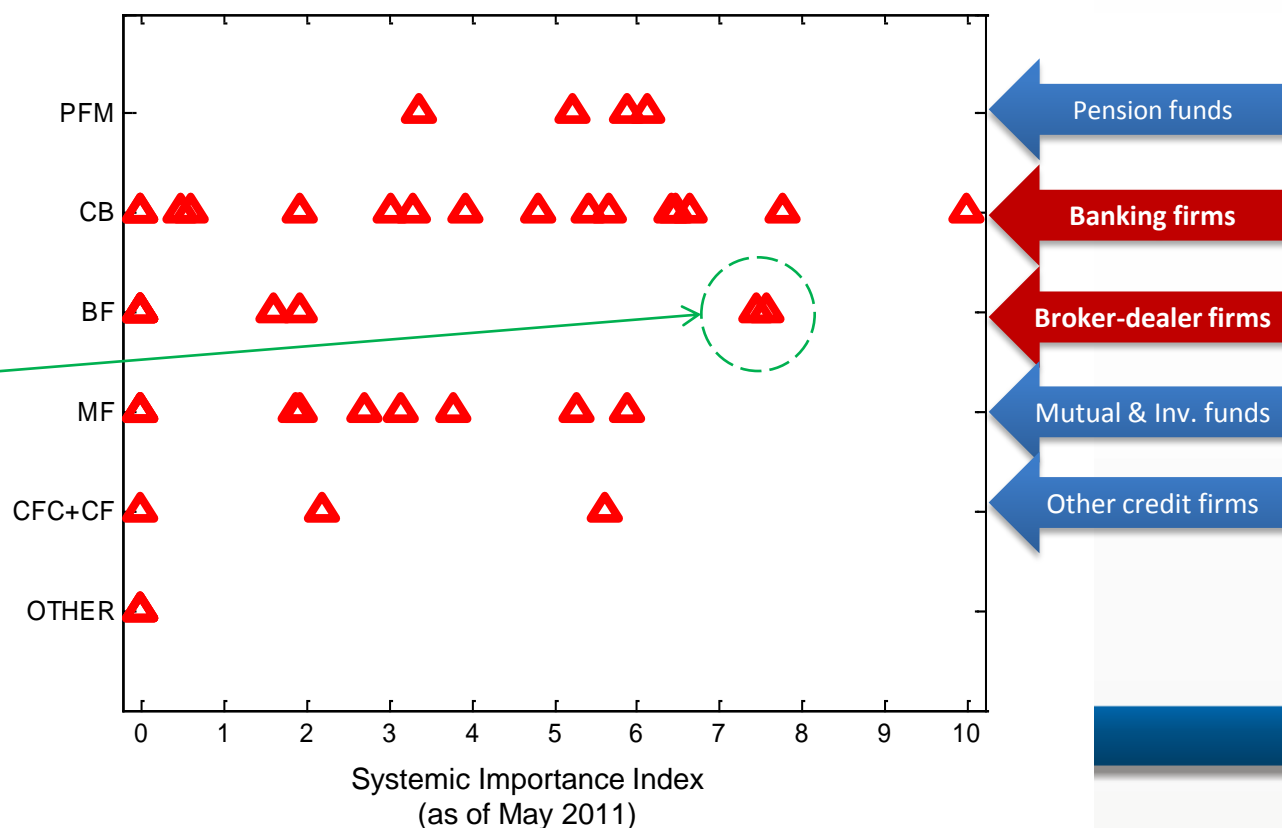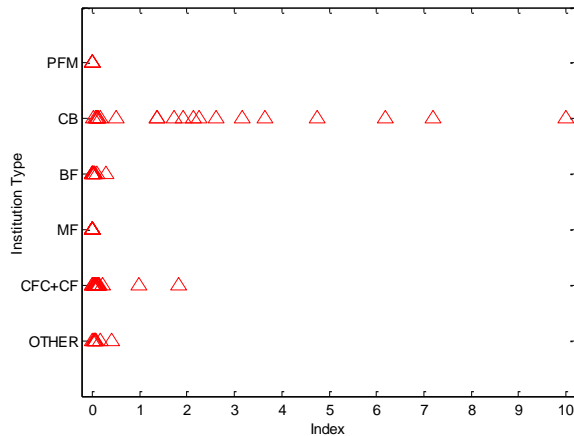

- **Two broker-dealer firms are systemically more important than the average banking firm!**
- **Everyone knew it, but there was no assessment to prove it.**

Pension funds

Banking firms

Broker-dealer firms

Mutual & Inv. funds

Other credit firms

Systemic Importance Index
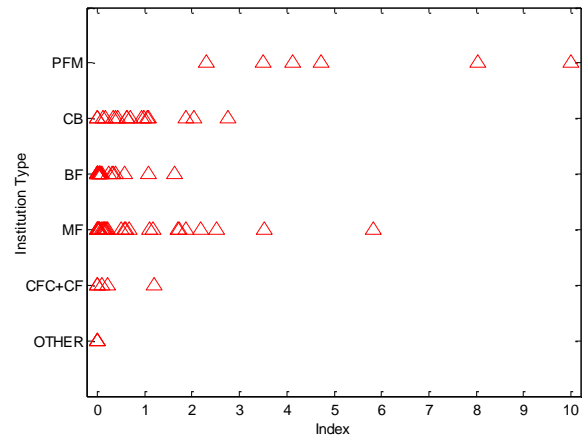(as of May 2011)

The systemic importance index

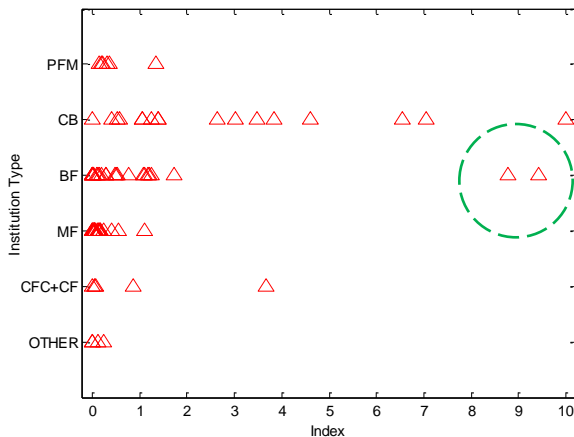- Where does the systemic importance come from for each institution?
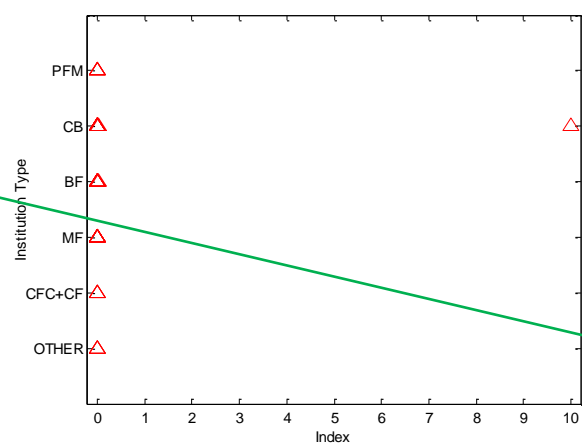

[A] Volume of deposits and money market borrowing

[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.

Final remarks

- The proposed methodology allowed for:

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

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**?