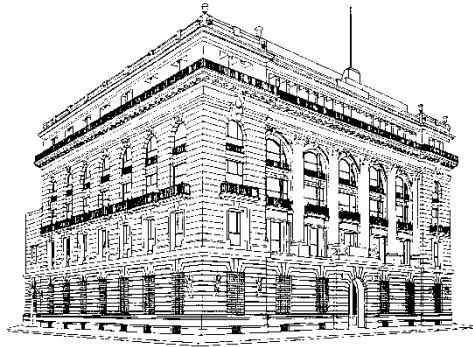


# Network Models for Systemic Risk Monitoring



May 2010.

  
BANCO DE MEXICO

## **I. Motivation**

- a) Relevant concepts**
- b) Related Literature**

## **II. The network model for systemic risk**

- a) Conceptual model**
- b) Simulation model**

## **III. Some results**

## **IV. Conclusions**



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# Definition for Systemic Risk

1. Systemic Risk is the risk of experiencing an event that threatens the well functioning of the system of interest (payments, banking, financial)
  
2. Systemic risk consists of two main components (Rochet 2009, Marquez & Martinez-Jaramillo 2009):
  - a) An initial (macroeconomic) shock, and
  - b) A contagion mechanism.



# Financial Contagion and Systemic Risk

1. Financial contagion has been used interchangeably with systemic risk, something that is not fully accurate.
2. However, as it was shown in the definition, contagion is just one of the components of a systemic event (a very important one though).
3. Moreover, the relevance of the (macro)economic environment is crucial.



# Network models, financial contagion and systemic risk

Since the influential paper by Allen and Gale (1998), network models have been used to study financial contagion.

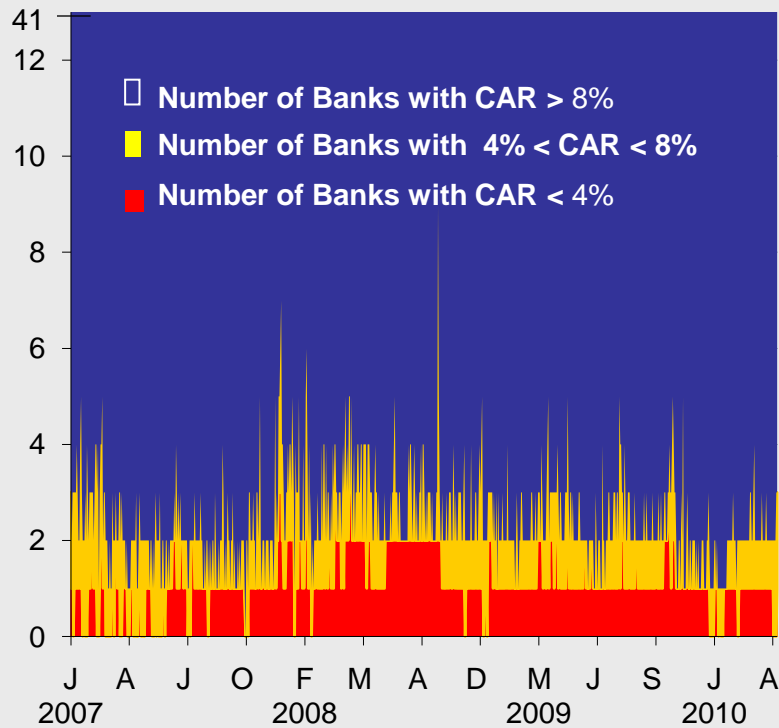
Network models are very appealing to study financial contagion and systemic risk for the following reasons:

- They are very intuitive,
- There is a vast amount of knowledge and analytical tools in this area, and
- There are many practical tools, software and interfaces available.



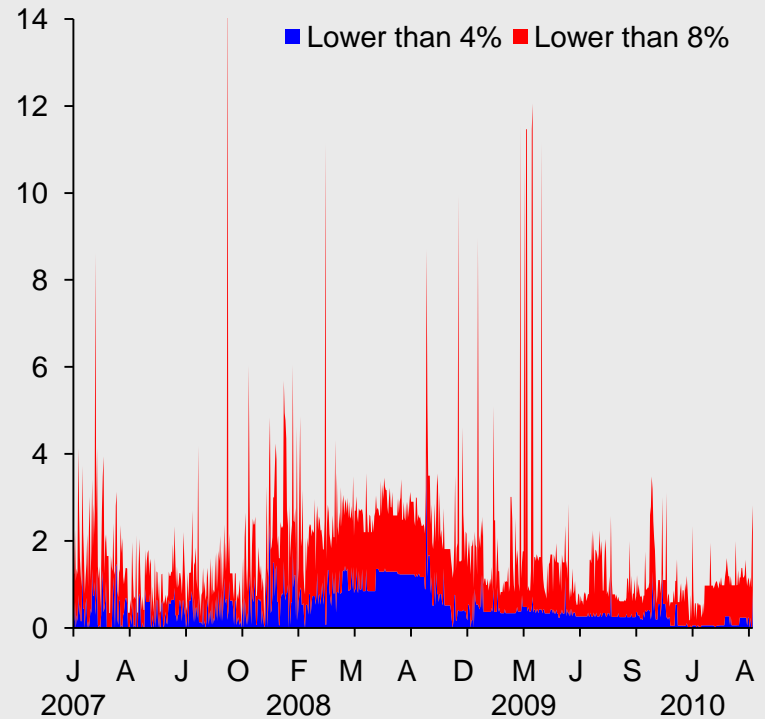
# I. Interconnectedness: Contagion Risk

**Capital Adequacy Indexes arising from a worst chain of Contagion occurring daily**  
(Number of banks)



Source: Banco de México.

**Assets of banks whose capital would be affected in the event of a worst chain of contagion occurring daily**  
(Percentage of total banking assets)



Source: Banco de México.



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# Financial Contagion.

1. Direct contagion in banking systems through the interbank market has been widely studied by central banks in several countries, Upper(2007).
  - Maximum entropy assumption.
  - Individual idiosyncratic failures.
2. More recently contagion and systemic risk have been studied recurring to Network Theory, Muller (2006), Nier et al. (2006), Babus (2007), Mistrulli (2007), Markose et al. (2009).



# Systemic Risk

1. Goodhart et al. (2006) propose a general equilibrium model which includes heterogeneous agents, endogenous defaults and credit and deposit markets.
2. Segoviano and Goodhart (2009) infer the multivariate density, which they use to derive relevant measures of distress for individual banks, groups of banks and the distress on the system due to an individual bank.
3. Boss et al. (2006) use a simulation model which they use to estimate the distribution of losses for the system as a whole.
4. Aikman et al. (2009) put in place a complex simulation model to study financial stability.



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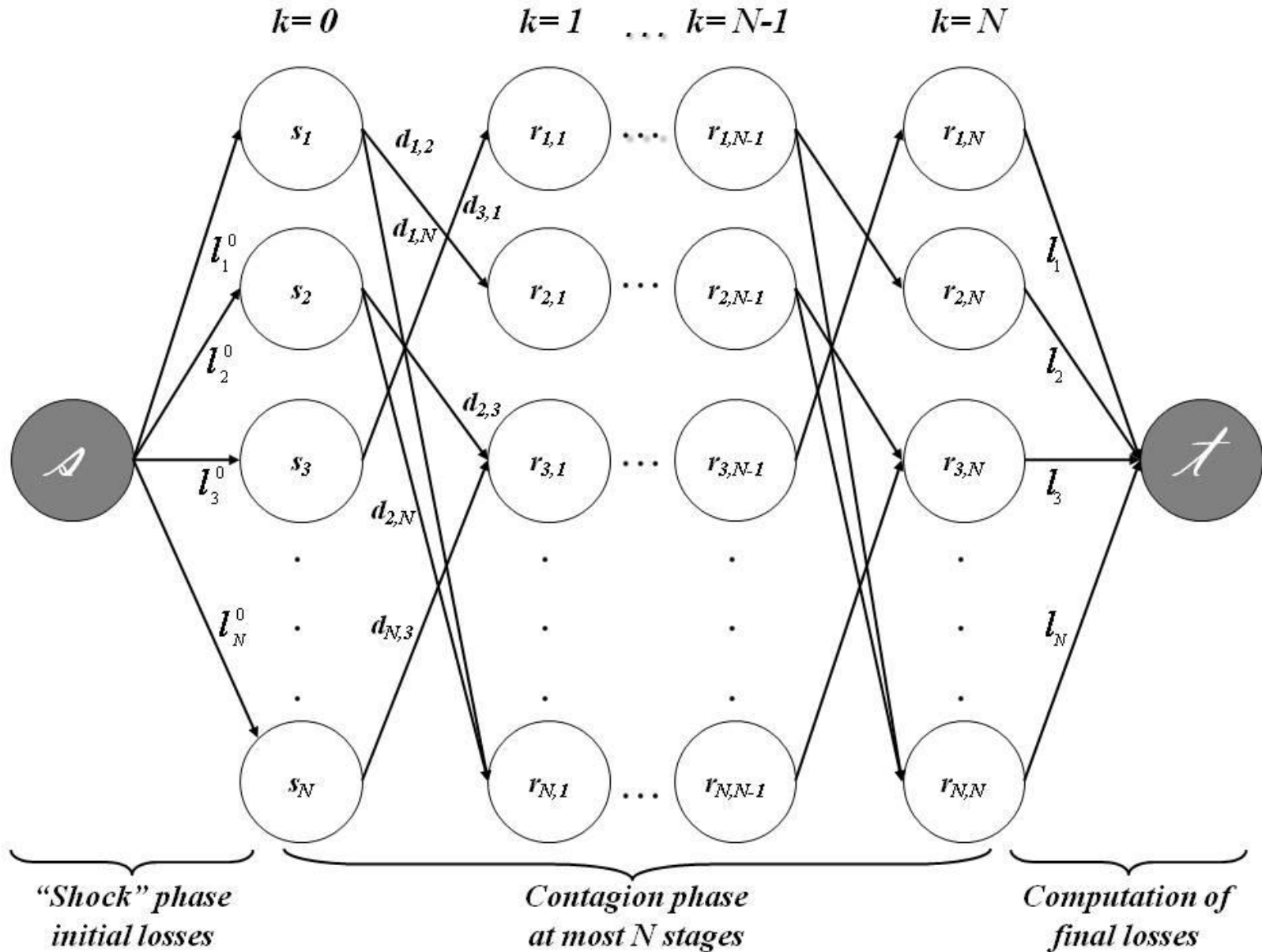
- a) Conceptual model**
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# The conceptual model





## **I. Motivation**

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- b) Related Literature**

## **II. The network model for systemic risk**

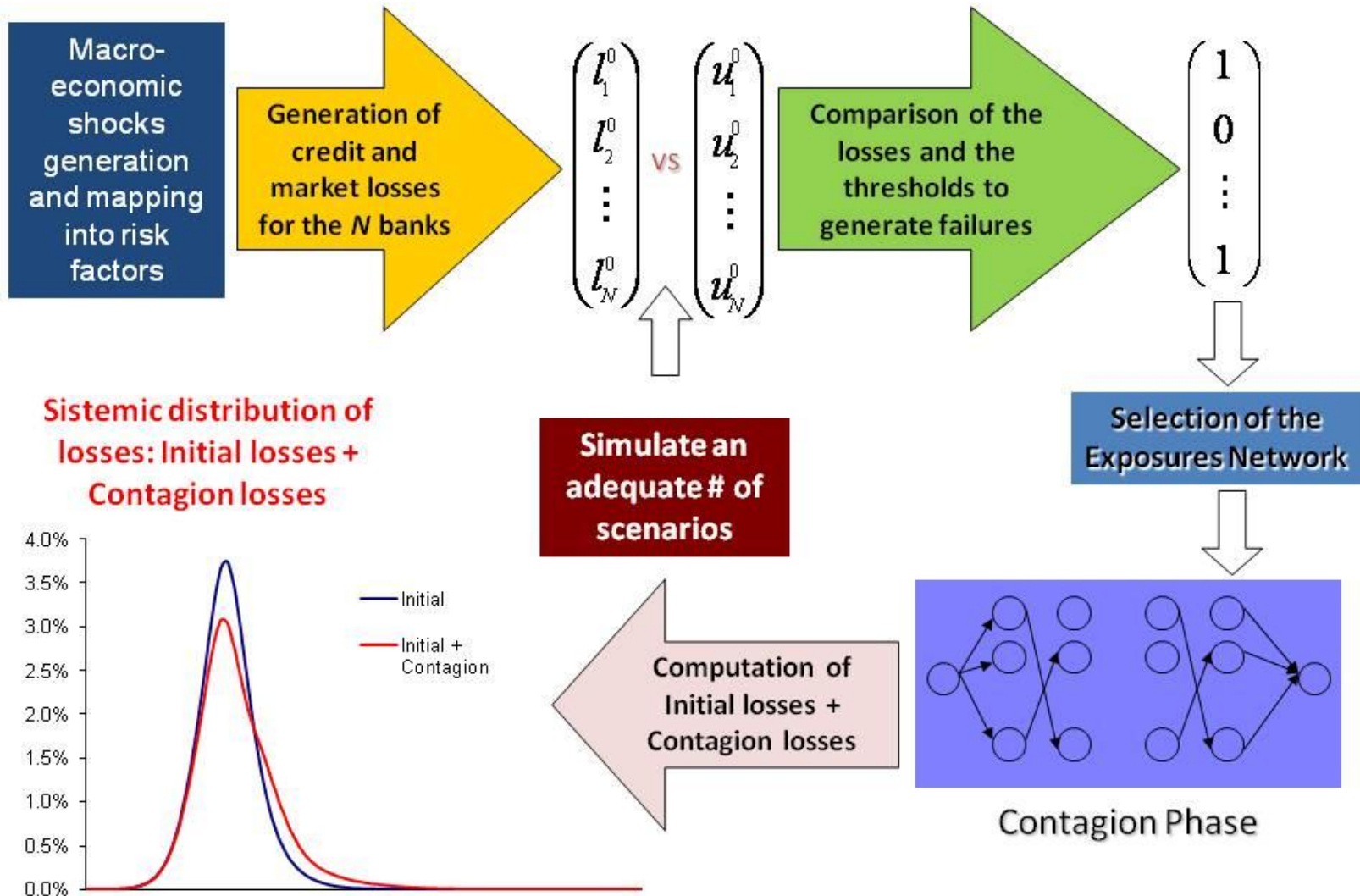
- a) Conceptual model**
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# The simulation model





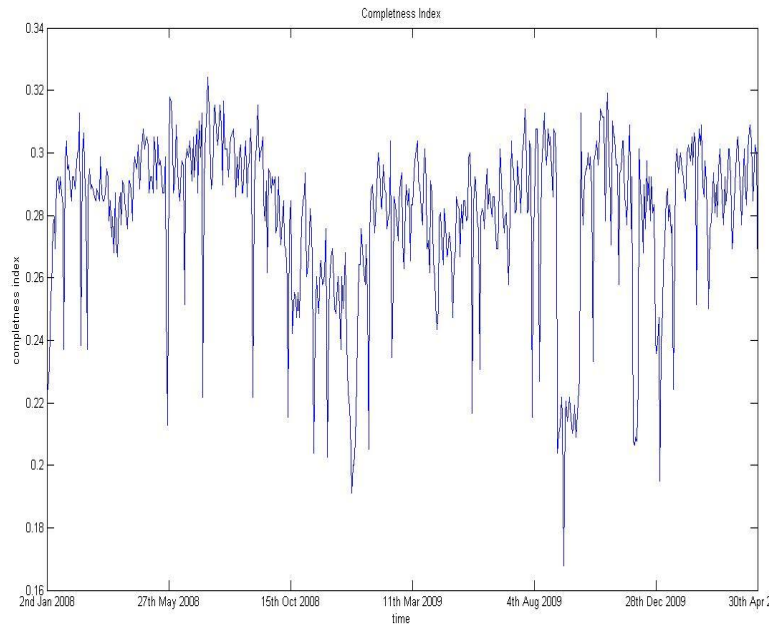
The data used to obtain the systemic distribution of losses for the Mexican banking system consists of:

1. The daily interbank exposures,
2. The macro economic information used to build the macro models (GDP, interest rates, stock indexes, etc),
3. The market portfolio,
4. Credit delinquency ratio as a proxy for the evolution of credit losses, and
5. The Tier 1 capital.



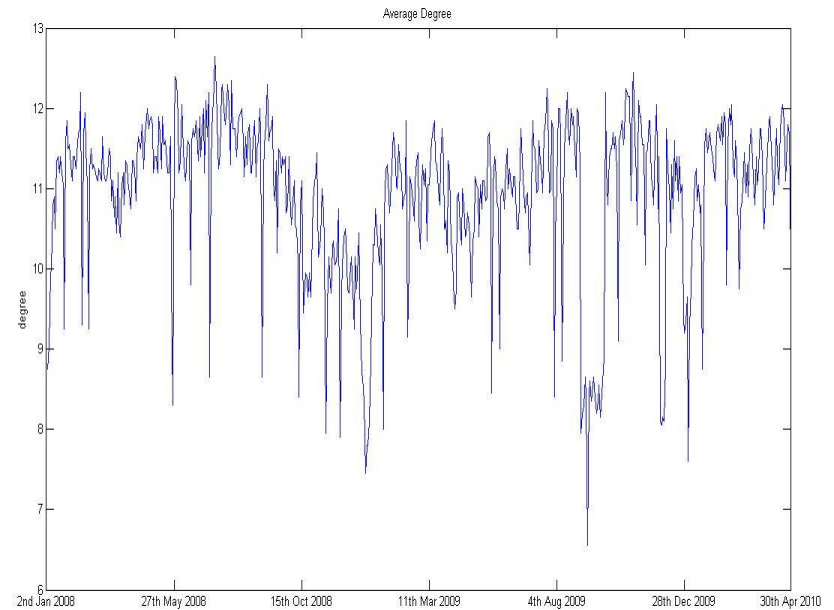
# The Interbank Market Network

## Completeness index



Source: Banco de México.

## Daily Average Degree



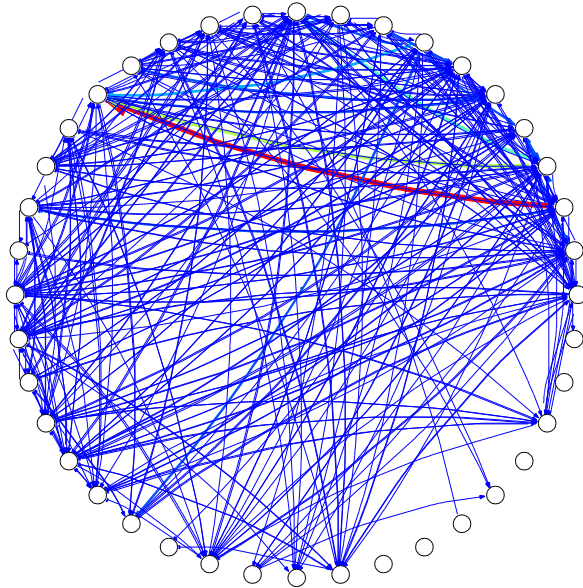
Source: Banco de México



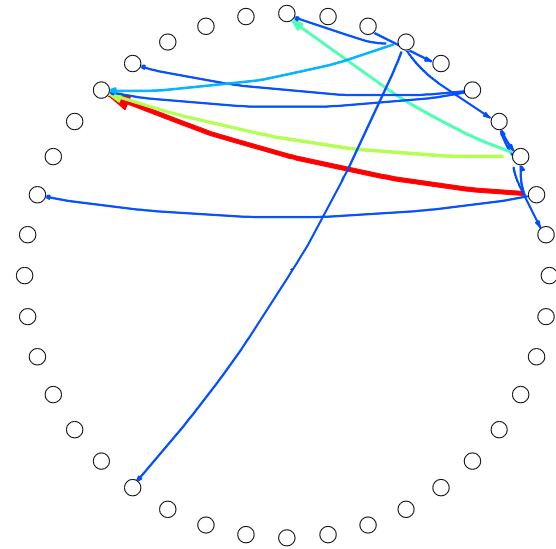


# The interbank market

**Interbank market  
January 27<sup>th</sup> 2008**



**Interbank market  
Largest exposures**



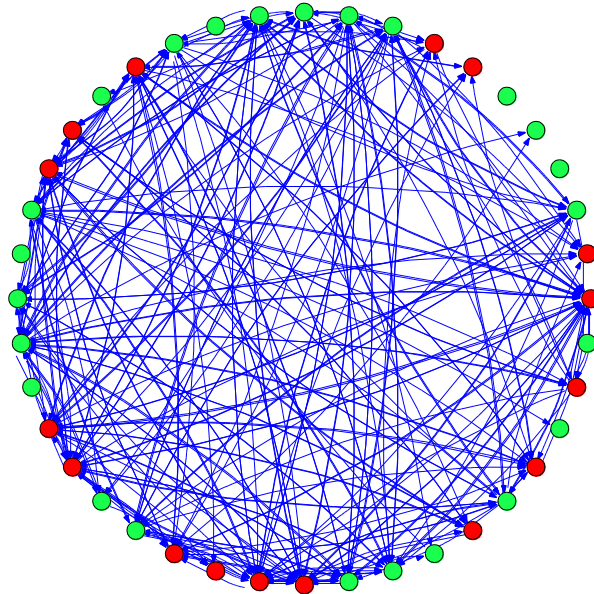
Source: Banco de México

Source: Banco de México



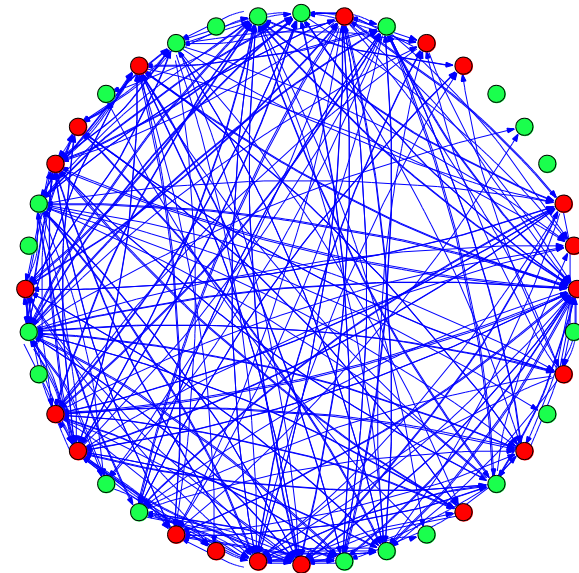
# Over-exposed banks

**Interbank market  
January 27<sup>th</sup> 2008**



**Over-exposed banks: 17**

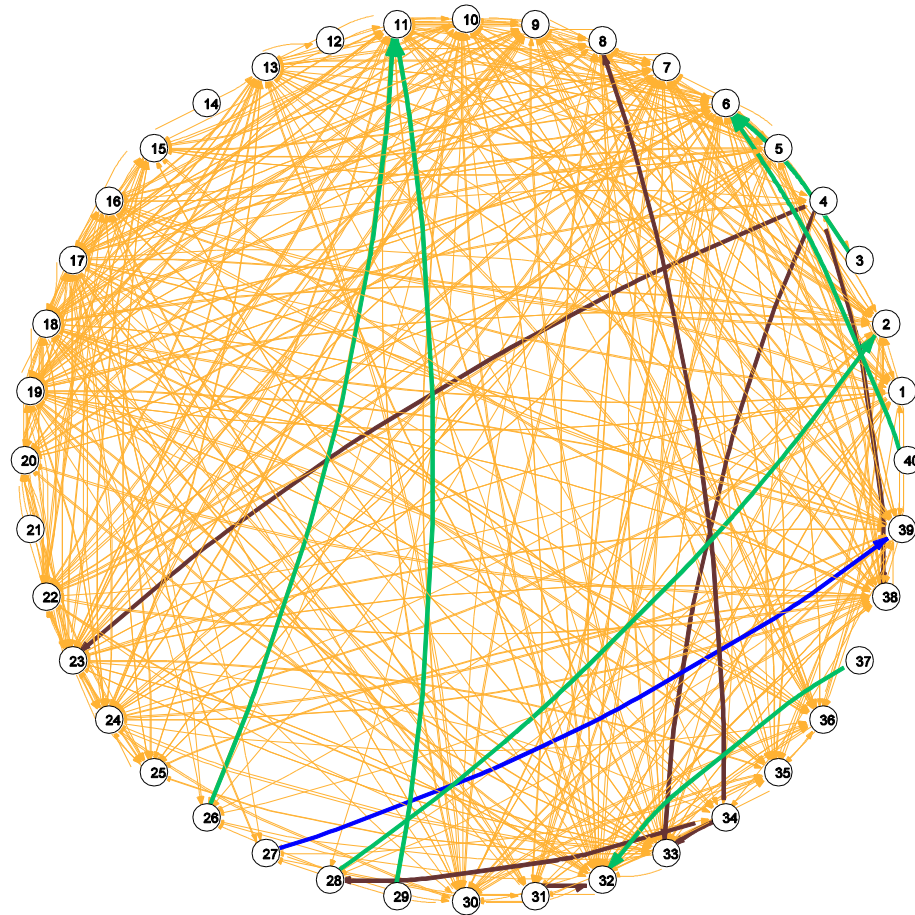
**Interbank market  
After an initial shock**



**Over-exposed banks: 19**

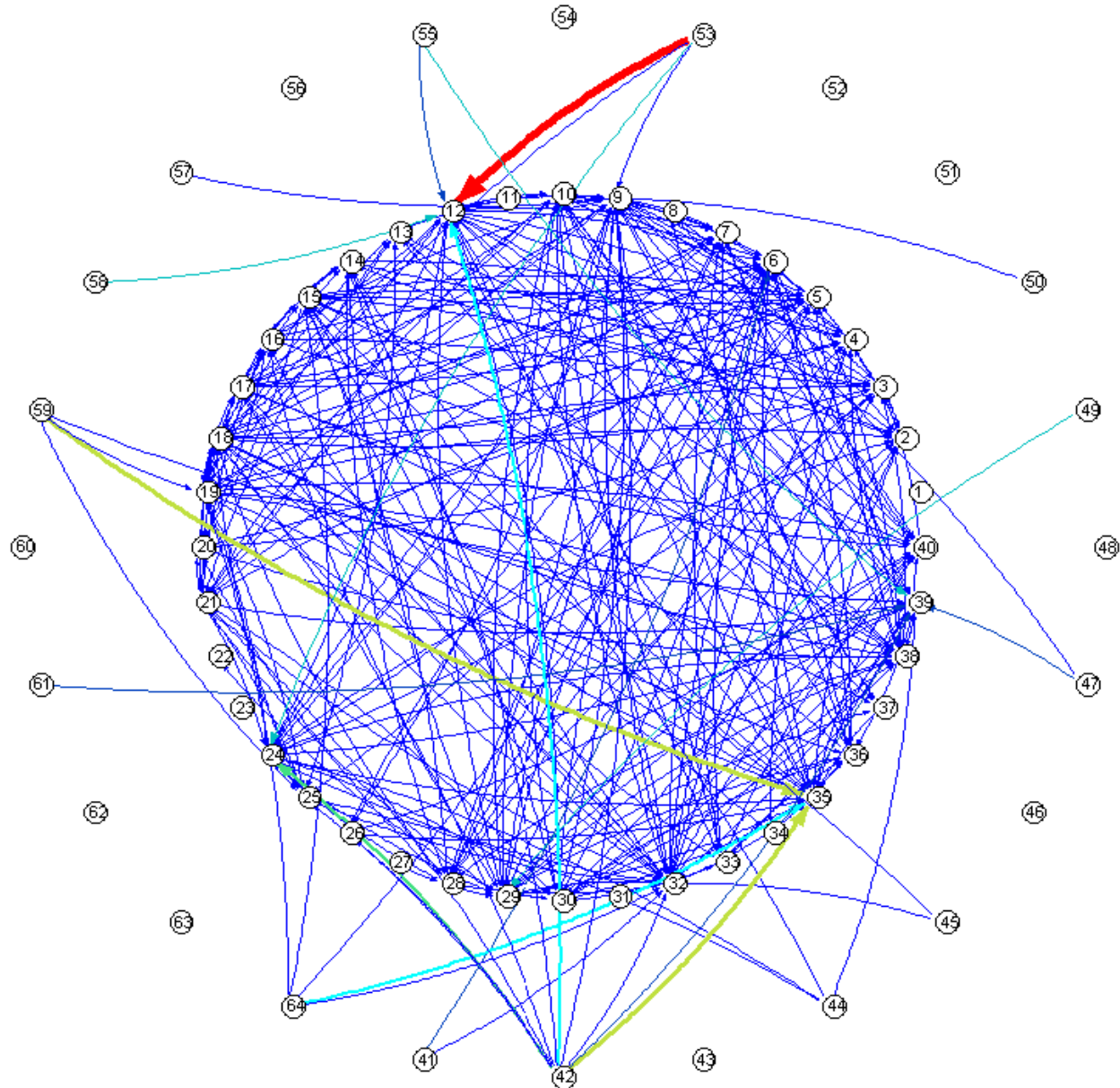


# Preference index





# International exposures





# Link to the economic variables I.

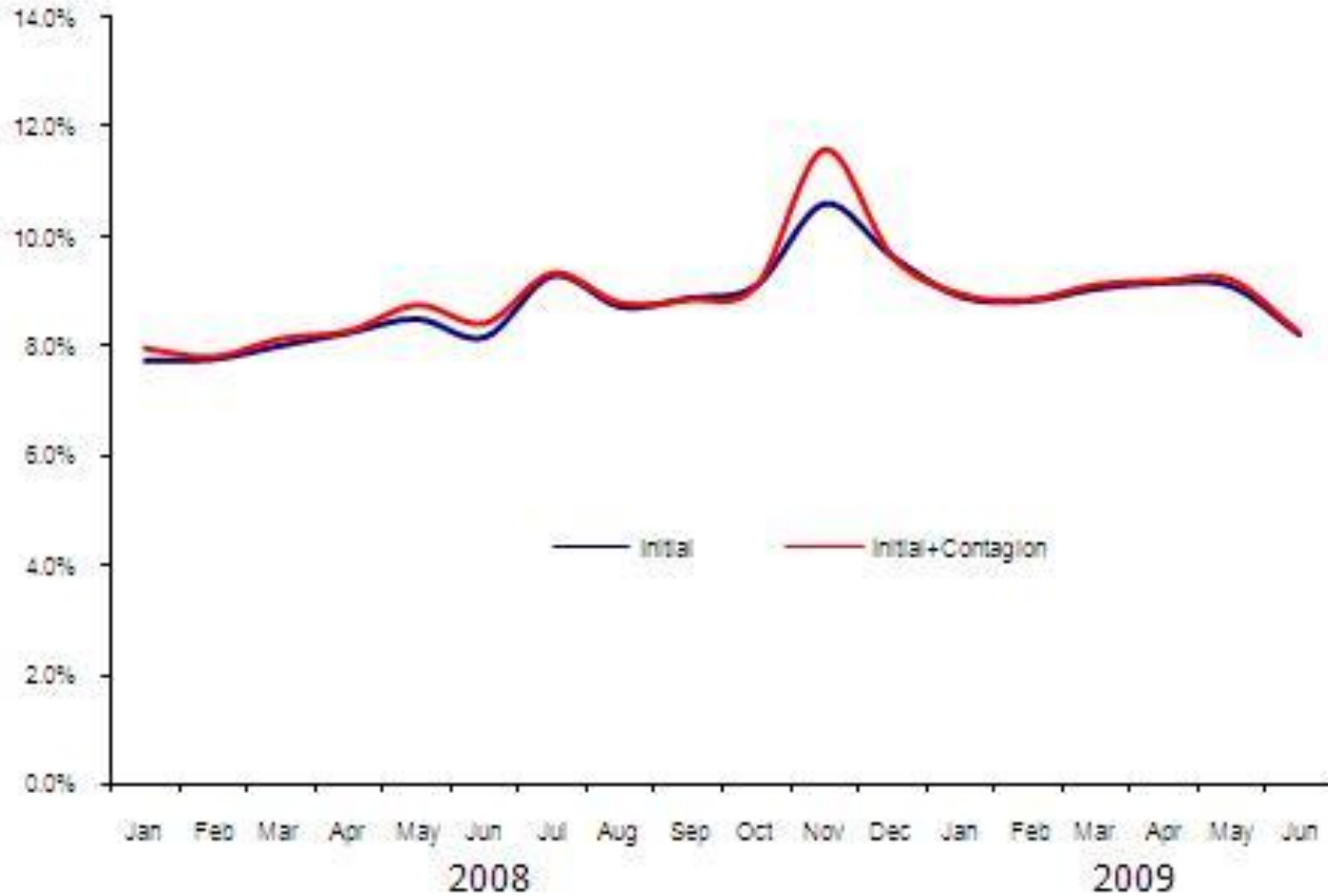
Previous versions of this work, Marquez Martinez-Jaramillo (2009), computed the joint distribution of losses from market and credit operations, and this distribution was used to generate "losses draws" and to determine whether those losses trigger a contagion process.

Despite the advantages of this method, behind each shock was the idea that "something happened" but there was few to say about what that "something" was.

Hence, to gain in the interpretation and to ease the stress testing procedure one of the aims is having scenarios with an economic interpretation.



# A measure of financial fragility: An example





# Link to the economic variables II.

To generate these scenarios linked to real economic variables within a consistent framework, a simple structural VAR was estimated:

$$Y_t = \sum_{i=1}^p A_i Y_{t-i} + \sum_{m=1}^{12} \delta_m D_{mt} + e_t. \quad (1)$$

National Variables	External Variables	Credit
IGAE (GDP proxy)	Treasury Bills rate	Commercial credit delinquency ratio
Cetes rate	Libor rate	Consumption credit delinquency ratio
INPC (Consumer Price Index)	Dow Jones Index	Mortgage delinquency ratio
FX (peso-dollar)	Bovespa stock index	
IPC (stock index)		
No. Insured workers at IMSS (unemployment		





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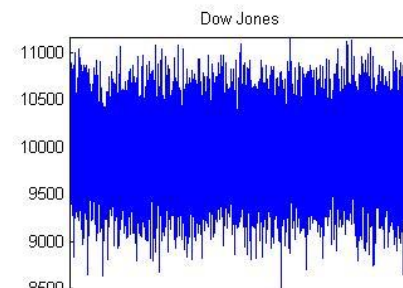
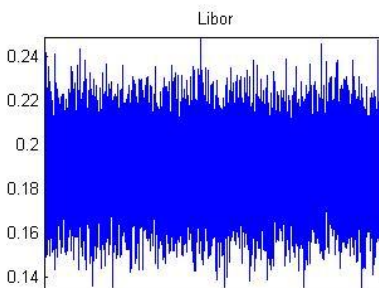
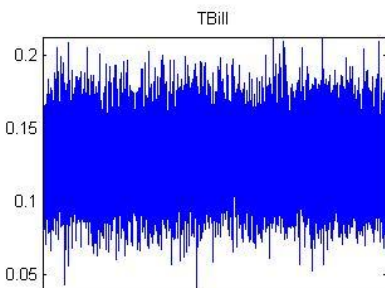
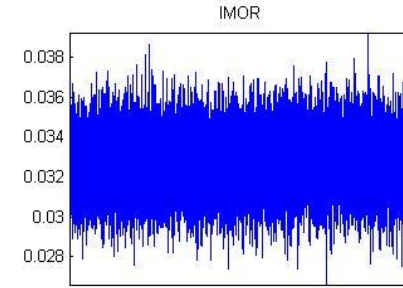
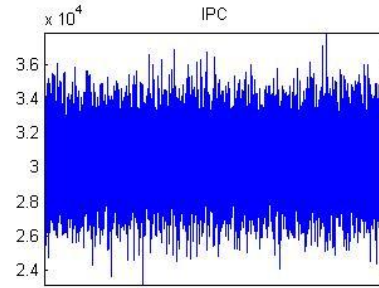
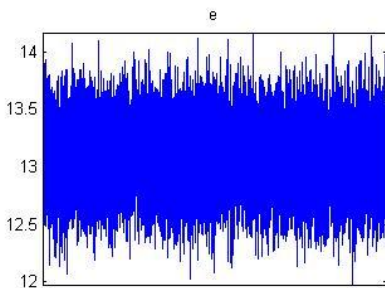
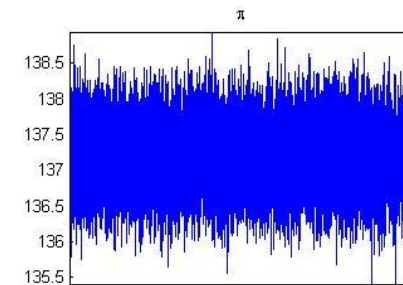
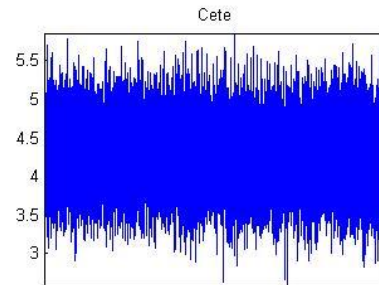
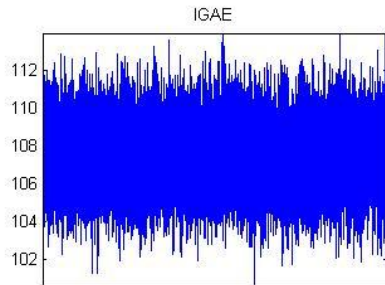
## **III. Some results**

## **IV. Conclusions**





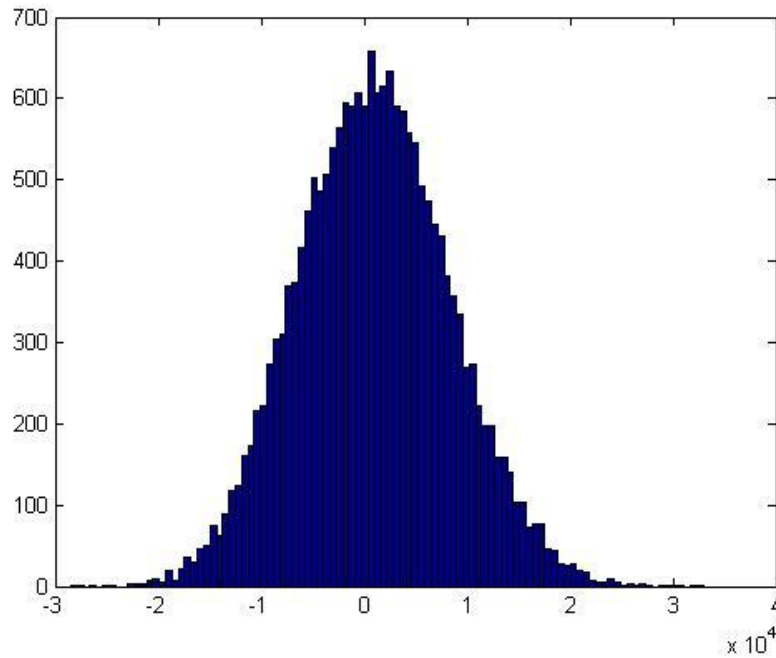
# Normal Scenarios





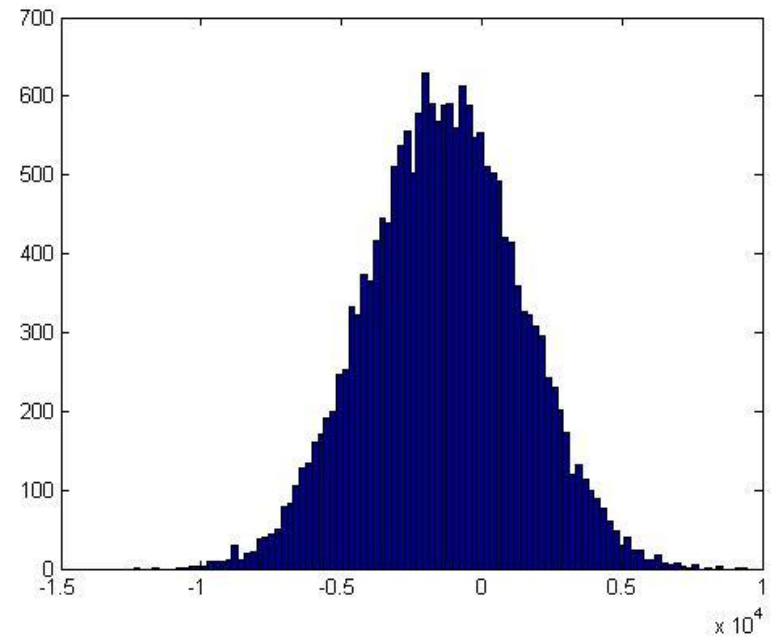
# Distribution of losses

## Market distribution of losses



Source: Banco de México

## Credit distribution of losses



Source: Banco de México



# Definition of CoVaR

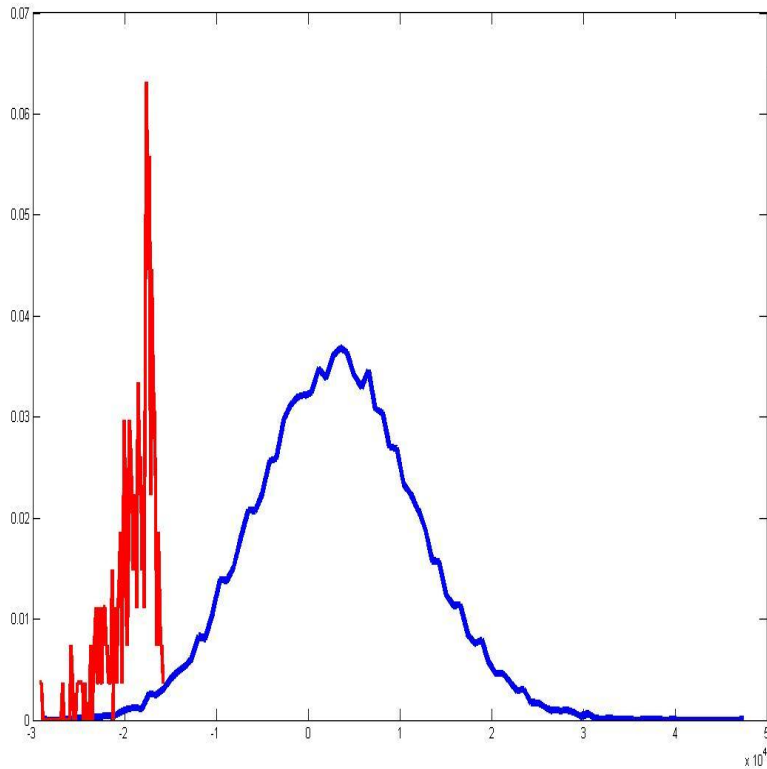
Institution  $i$ 's CoVaR relative to an institution  $j$  (the system) is defined as the  $VaR$  of the institution  $j$  (or the whole financial sector) conditional on institution  $i$  being in distress.

$$Pr(X^j \leq CoVaR_q^{j|i} | X^i = VaR_q^i) = q.$$

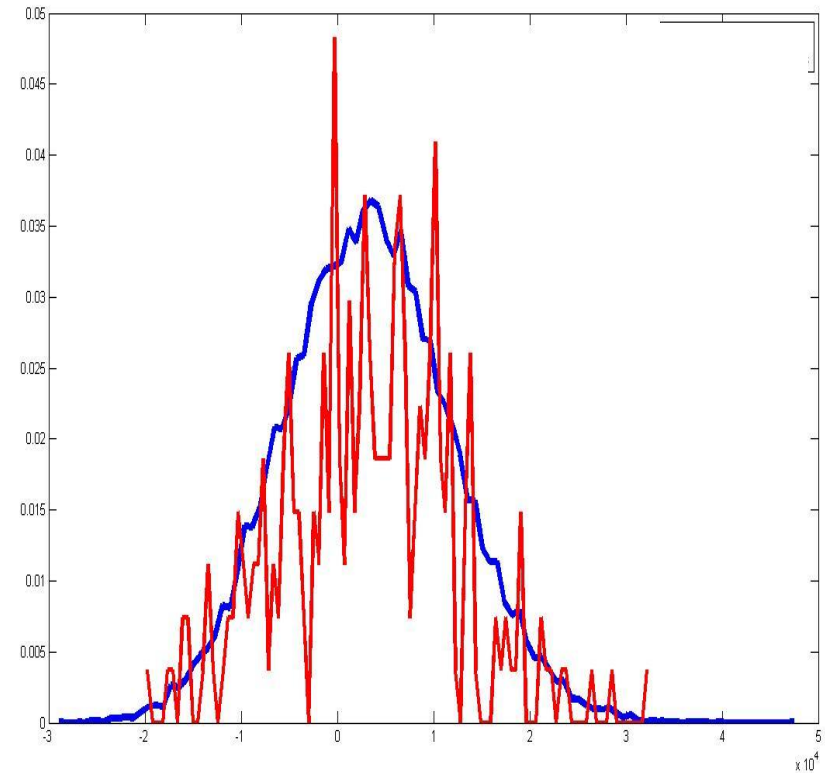
The difference between the  $CoVaR$  and the unconditional financial system  $VaR$ ,  $\Delta CoVaR$ , captures the marginal contribution of a particular institution to the overall systemic risk.



# CoVaR



**Distribution of losses for the system and conditional distribution given that the big banks' losses are at their VaR level.**



**Distribution of losses for the system and conditional distribution given that the medium size banks' losses are at their VaR level.**

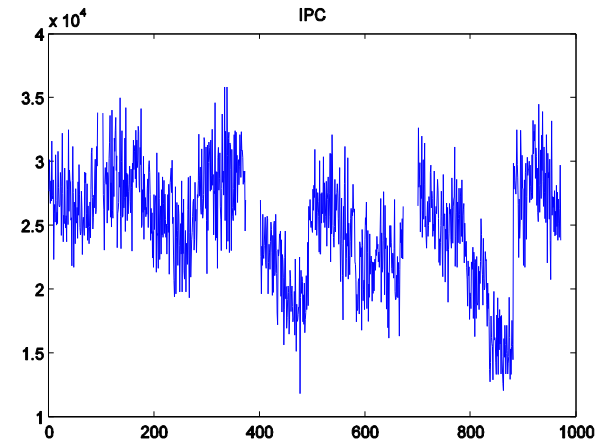
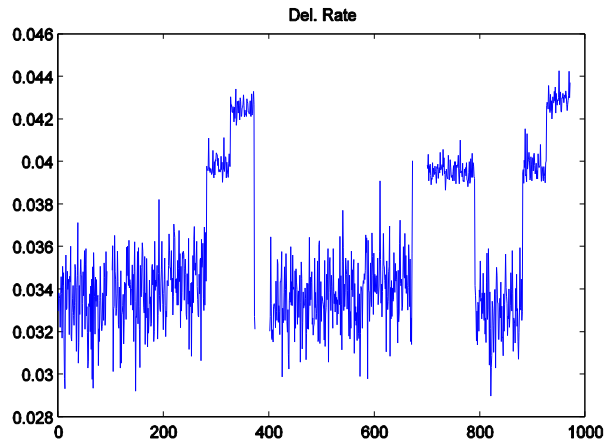
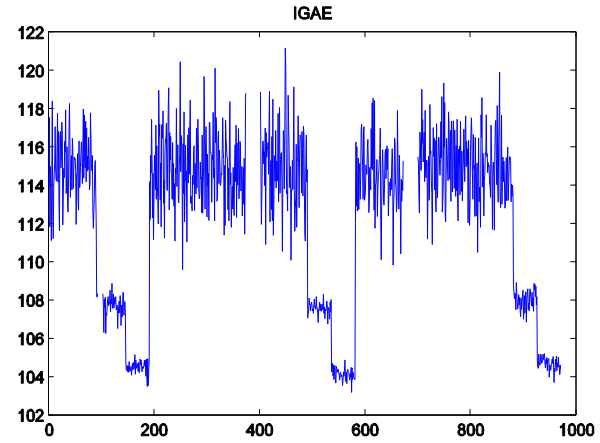
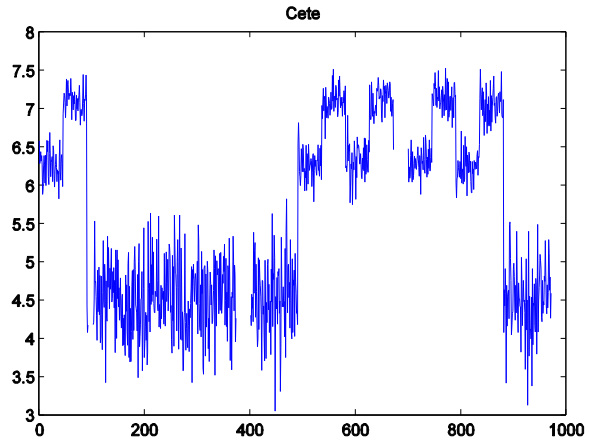


# Systemic events

- Contagion did not happen under the previous 20k simulations.
- Contagion did happen under Montecarlo simulation (5m).
- Systemic events are located on the tail.



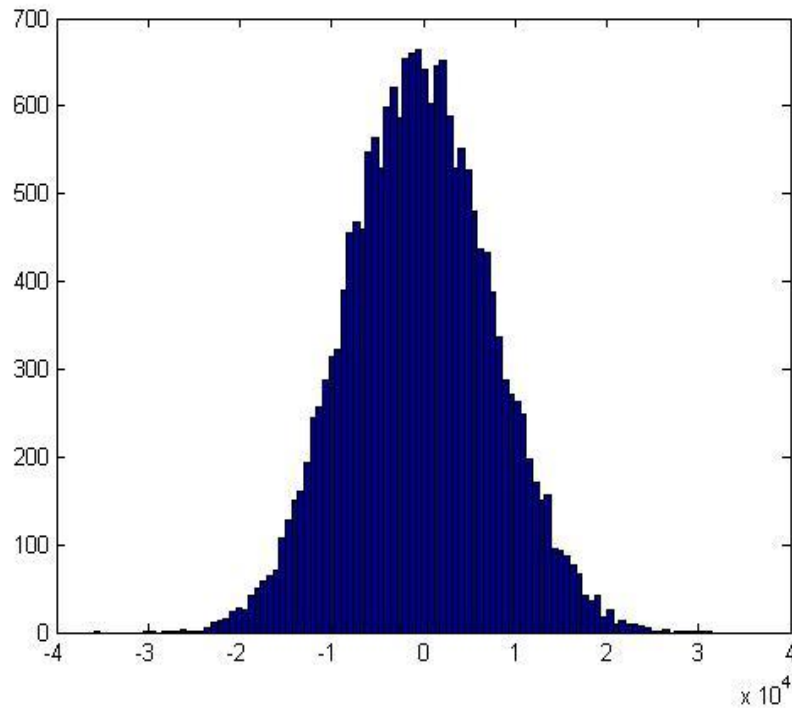
# Stress scenarios



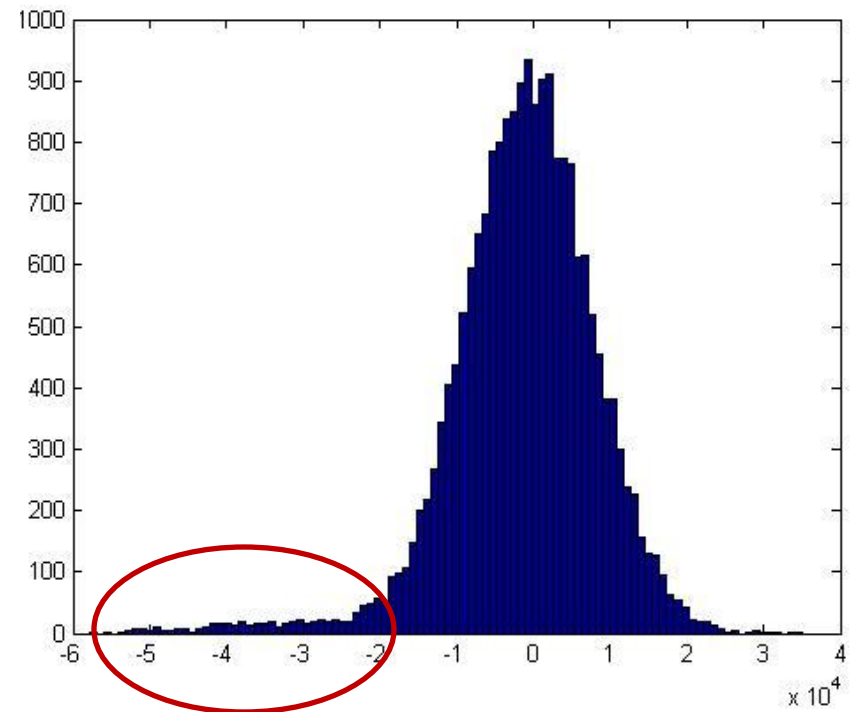


# Joint tail distribution

**Joint distribution of losses  
Normal scenarios**



**Joint distribution of losses  
Including stress scenarios**

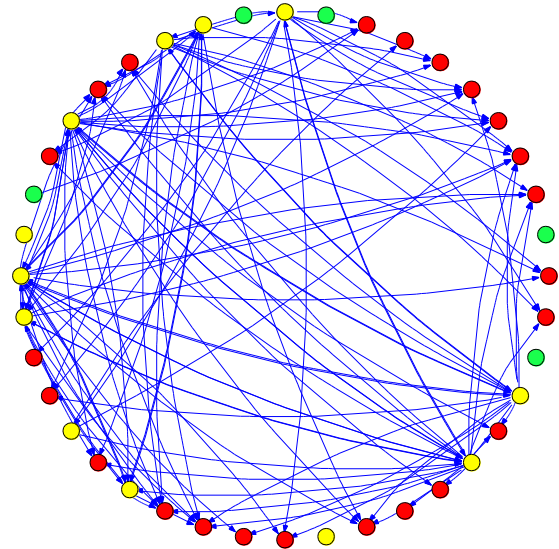
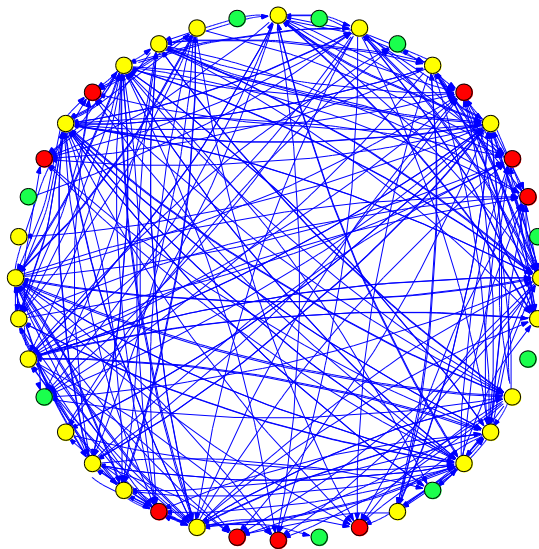
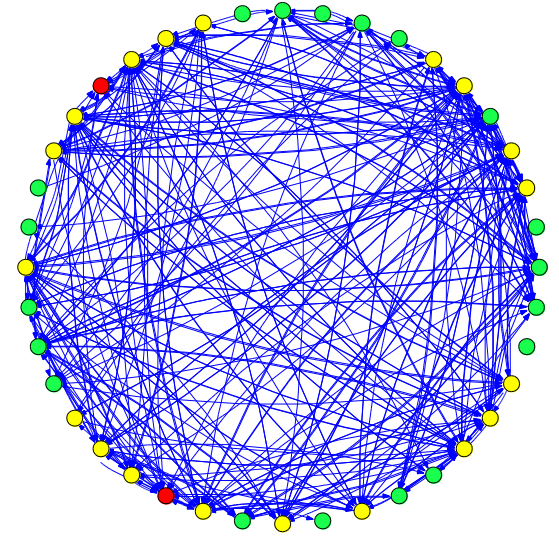
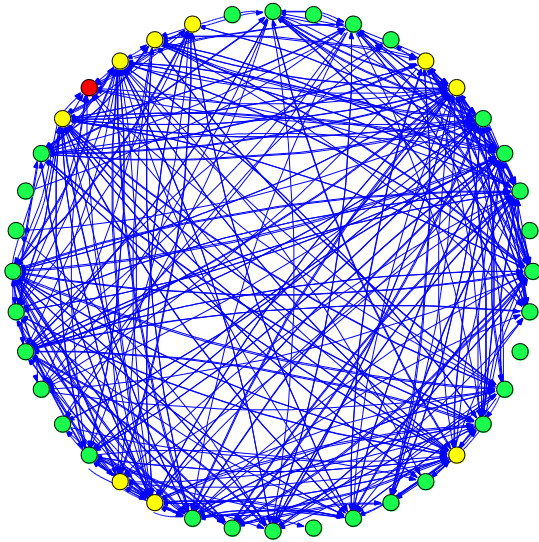


Source: Banco de México

Source: Banco de México



# Contagion under stress







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# Conclusions

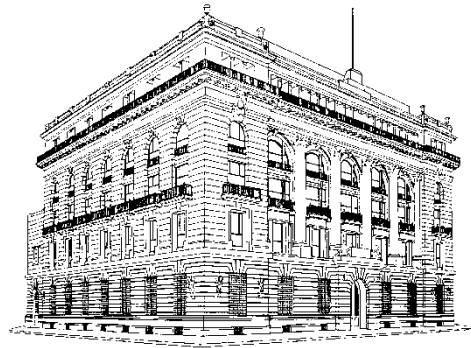
The literature adhered to the belief that the topology of the network was enough to characterize the systemic riskiness of a particular financial system.

The relevance of the initial macroeconomic shock should not be disregarded.

Finally, to concentrate on size and interconnectedness (alone) to determine the systemic importance of institutions could be misleading.

There are another aspects which are very important as well. For example: the size of the losses, the relationship between the capacity of a bank to absorb losses and its exposure on the interbank market.

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