Financial Networks and Regulation

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Papers

- Financial Networks and Monitoring Systemic Risk

(joint work with Thiago C. Silva and Sérgio S. Souza)

- Financial Networks and Stress Tests

(joint work with Thiago C. Silva and Michel Silva)

Contributions

1. We propose two new network measures that have clear systemic risk interpretation
2. We derive theoretical properties for these network measures
3. We show how these measures evolve over time using a unique dataset on complete exposures for the Brazilian financial market
4. We show how these measures can be useful for the surveillance of financial networks
5. Need for Financial Regulation

Impact Susceptibility: Definition

- We define impact susceptibility as how likely it is for a financial institution to receive impacts originated from arbitrary regions in the network
- Measures the **potential contagion** of market participants
- Unlike DebtRank, **it does not depend on initial stress scenarios**
  - Impact susceptibility finds the intrinsic risk within the financial network, without the need of external shocks
- **Both measures complement each other**
  - **DebtRank:** “to be” network given initial shock
  - **Impact susceptibility:** “as is” network

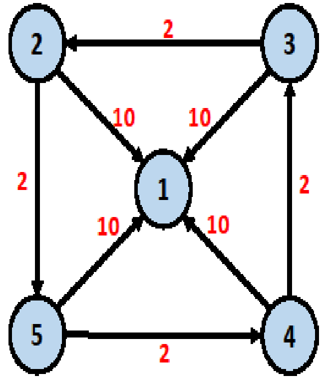
Impact Susceptibility: Definition

- Relies on the **communicability** between financial institutions
  - Uses weighted combinations of shortest paths and walks of several lengths that we compute using the vulnerability matrix constructed from the financial network
- A directed connection exists in the vulnerability matrix when the default of an entity leads another institution into default
  - Hence, the vulnerability matrix captures the notion of the importance of the FIs’ liabilities in relation to available capital buffers of their neighborhood.

Vulnerability network

- Combination of **network topology** (lending operations) and **capital buffers**

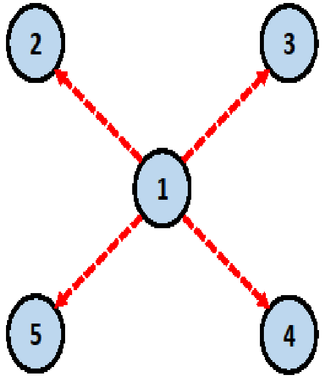
Robust in topology yet fragile in contagion



Dimension: Network topology

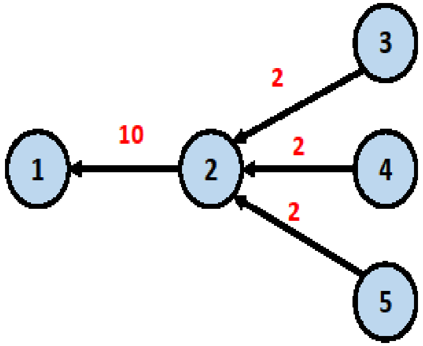
Bank	Capital Buffer
1	1
2, 3, 4, 5	7

Dimension: Capital buffer distribution



Risk dimension: vulnerability matrix

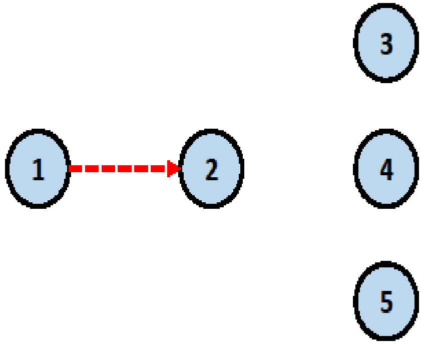
Fragile in topology but robust in contagion



Dimension: Network topology

Bank	Capital Buffer
1	1
2	7
3, 4, 5	1

Dimension: Capital buffer distribution



Risk dimension: vulnerability matrix

Impact Susceptibility: Definition

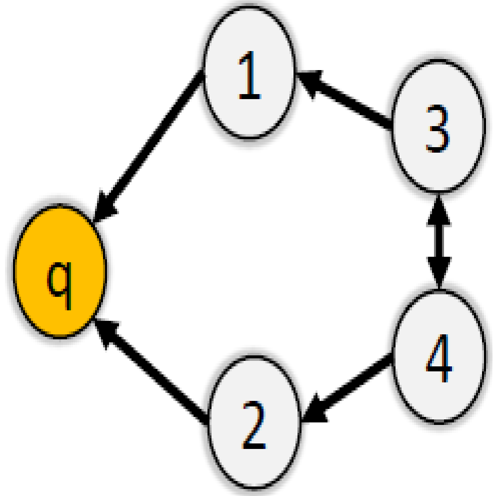
$$S_q(\mathbf{G}(\bar{\mathbf{V}})) = \begin{cases} \frac{1}{k_q^{(\text{in})}(\bar{\mathbf{V}})} \sum_{\substack{p \in \mathscr{V} \\ p \neq q}} \mathbf{G}_{pq}(\bar{\mathbf{V}}), & \text{when } k_q^{(\text{in})}(\bar{\mathbf{V}}) > 0 \\ 0, & \text{otherwise} \end{cases}$$

where $k_q^{(\text{in})}(\bar{\boldsymbol{V}})$ is the number of counterparties to which q is directly exposed and can lead it to default, i.e. it is the number of counterparties p such that $\boldsymbol{G}_{pq}(\bar{\boldsymbol{V}}) > 0$. $\bar{V}_{kq} = 1$ only when bank k's liabilities towards q surpasses q's capital buffer.

$$\mathbf{G}_{pq}(\mathbf{M}) = \frac{1}{s!}\mathbf{P}_{pq} + \sum_{k>s} \frac{1}{k!}(\mathbf{M}^k)_{pq} = (e^{\mathbf{M}})_{pq}$$

Definition 1. ***Remote vulnerability:*** *we say that institution q is remotely vulnerable when* $\exists p \in \mathscr{V}$ *and* $k > 1 : (\bar{\mathbf{V}}^k)_{pq} > 0.$

Theorem 1. $S_q > 1$ *if and only if* q *is remotely vulnerable.*



q is remotely vulnerable to indirect neighbors 3 and 4

If an FI has $S_q > 1$, then it can suffer impacts from indirect neighbors, requiring greater surveillance – additional capital requirements.

Impact Diffusion Influence: Definition

- Captures the notion of how influent one institution is in terms of diffusing impacts over the network
- Impact diffusion influence is the **opposite perspective** of the impact susceptibility
- We can understand the diffusion influence of an FI q in terms of the variation it provokes on the communicability indices of all of the FIs when we remove q's power of diffusing impacts
- If the communicability decreases at a large extent, then that removed FI plays an important role in diffusing impact throughout the network.
- Conversely, if its removal slightly modifies the communicability between FIs, then it does not influence the impact diffusion process in the network

- Two orthogonal terms:

$$I_q(\bar{\mathbf{V}}) = I_q^{(\text{start})}(\bar{\mathbf{V}}) + I_q^{(\text{inter})}(\bar{\mathbf{V}})$$

$$I_q^{(\text{start})}(\bar{\mathbf{V}}) = \begin{cases} \frac{1}{k_q^{(\text{out})}(\bar{\mathbf{V}})} \sum_{\substack{p \in \mathscr{V} \\ p \neq q}} \mathbf{G}_{qp}(\bar{\mathbf{V}}), & \mathit{if}\ k_q^{(\text{out})}(\bar{\mathbf{V}}) > 0 \\ 0, & \mathit{otherwise} \end{cases}$$

$$I_q^{(\text{inter})}(\bar{\mathbf{V}}) = \begin{cases} \frac{1}{k_q^{(\text{out})}(\bar{\mathbf{V}})} \sum_{\substack{p \in \mathscr{V} \\ p \neq q}} \sum_{\substack{r \in \mathscr{V} \\ r \notin \{q,p\}}} \left[\mathbf{G}_{pr}(\bar{\mathbf{V}}) - \mathbf{G}_{pr}(\bar{\mathbf{V}}^{(q-)})\right], & \mathit{if}\ k_q^{(\text{out})}(\bar{\mathbf{V}}) > 0 \\ 0, & \mathit{otherwise} \end{cases}$$

where $k_q^{(\text{out})}(\overline{\boldsymbol{V}})$ is the number of counterparties that q can lead into default

Impact Diffusion Influence: Definition

where $I_q^{(\mathrm{start})}(\bar{\mathbf{V}})$ *quantifies the potential influence of q on starting impacts and* $I_q^{(\mathrm{inter})}(\bar{\mathbf{V}})$ *indicates the same for impacts that do not start at q, but necessarily pass through it in the chaining effect. In this second term, q acts as a potential intermediator by transmitting the impact, in principle, to its direct neighbors.*

Definition 2. ***Remote contagious:*** *we say that institution q is remotely contagious when $\exists p \in \mathscr{V}$ and $k > 1 : (\bar{\mathbf{V}}^k)_{qp} > 0$.*

Lemma 4. *$I_q^{(\text{start})} > 1$ if and only if q is remotely contagious.*

Theorem 3. *If q is remotely contagious, then $I_q > 1$.*

If an FI has $I_q > 1$, then it can induce default in indirect neighbors

Too-central-to-fail?

Weighted Impact Diffusion Influence: Definition

- Institutions can have large influence in propagating impacts, but only to non-important institutions. Conversely, one institution may have low influence in propagating impact or losses and still have the potential to cause a devastating impact on the financial system

Weighted Impact Diffusion Influence: Definition

- Therefore, we also define a weighted version of the impact diffusion influence by modulating each potential impact to a corresponding proxy of importance of impacted institution
- Note that, while the non-weighted version provides a quantitative measure of how many entities are impacted, the weighted version also brings into play the importance of each of the impacted entities

$$I_q^{(\mathrm{w})}(\bar{\mathbf{V}}, P^{(\mathrm{value})}) = \frac{1}{k_q^{(\mathrm{out})}(\bar{\mathbf{V}})} \sum_{p \in \mathscr{V}} \sum_{\substack{r \in \mathscr{V} \\ r \neq p}} \left[\mathbf{G}_{pr}(\bar{\mathbf{V}}) - \mathbf{G}_{pr}(\bar{\mathbf{V}}^{(q-)}) \right] \cdot P_r^{(\mathrm{value})}$$

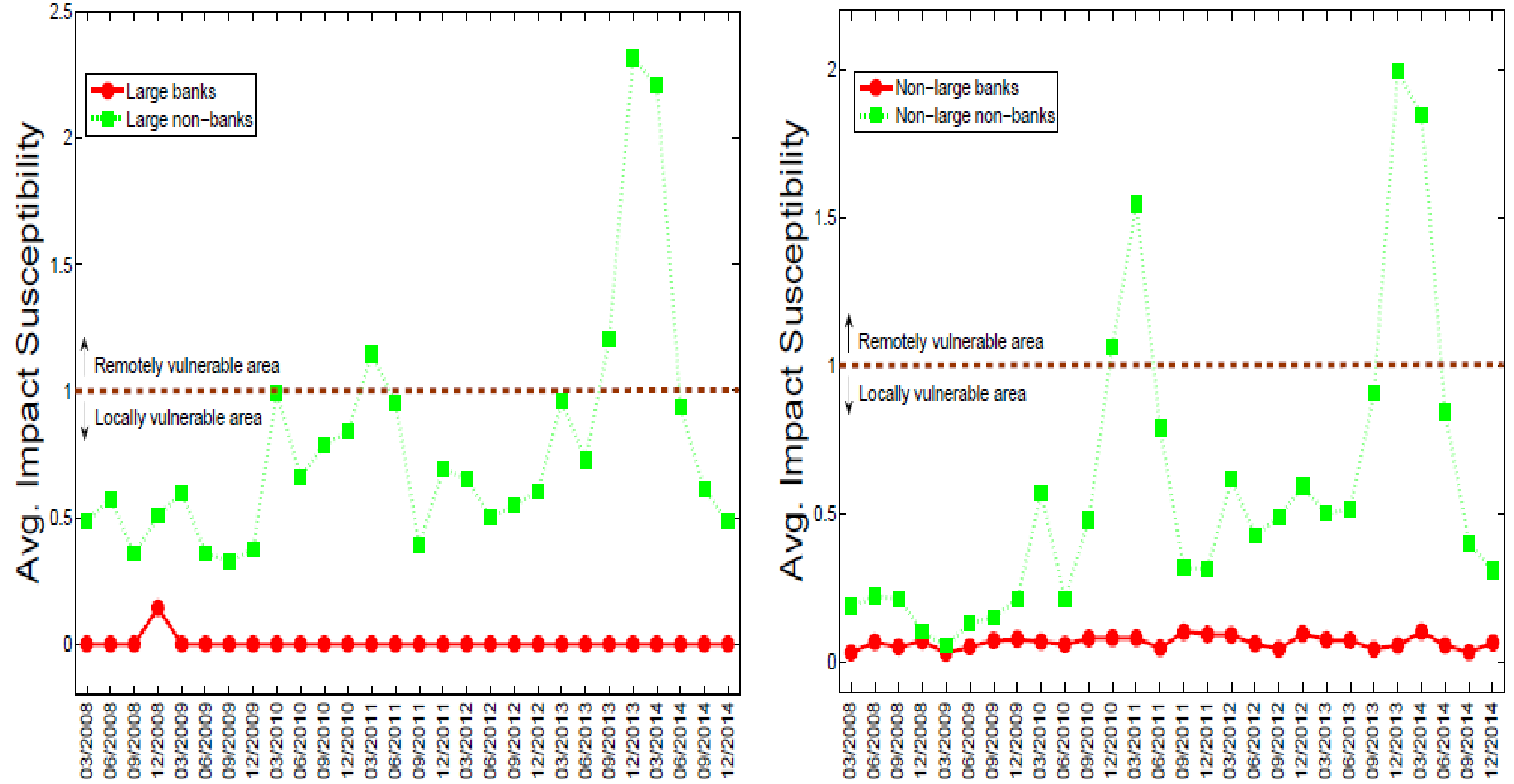
Empirical Data

- We use a unique Brazilian database with supervisory data
- From this database, we take quarterly information on Brazilian domestic financial market exposures, supervisory variables and balance sheet statements
- We use accounting information to evaluate the FIs' capital buffers from March 2008 through December 2014
- This information is vital to compute some network measurements, such as the impact susceptibility and its derived measures

Hypotheses and Definitions

- We define the capital buffer of an FI as the FI's total capital (Tier 1 + Tier 2 capitals) that exceeds 8% of its risk-weighted assets (RWA)
- In Brazil, the capital requirement is 13% or 15% for specific types of credit unions and 11% for other FIs, including banks
- We set 8% RWA as a reference for the computation of capital buffers as we assume that if an FI holds less than what is recommended by the Basel Committee on Banking Supervision (BCBS), i.e., 8% of its RWA, it will take longer to raise its capital to an adequate level and will likely suffer an intervention

Impact Susceptibility



(a) Impact susceptibility of large FIs

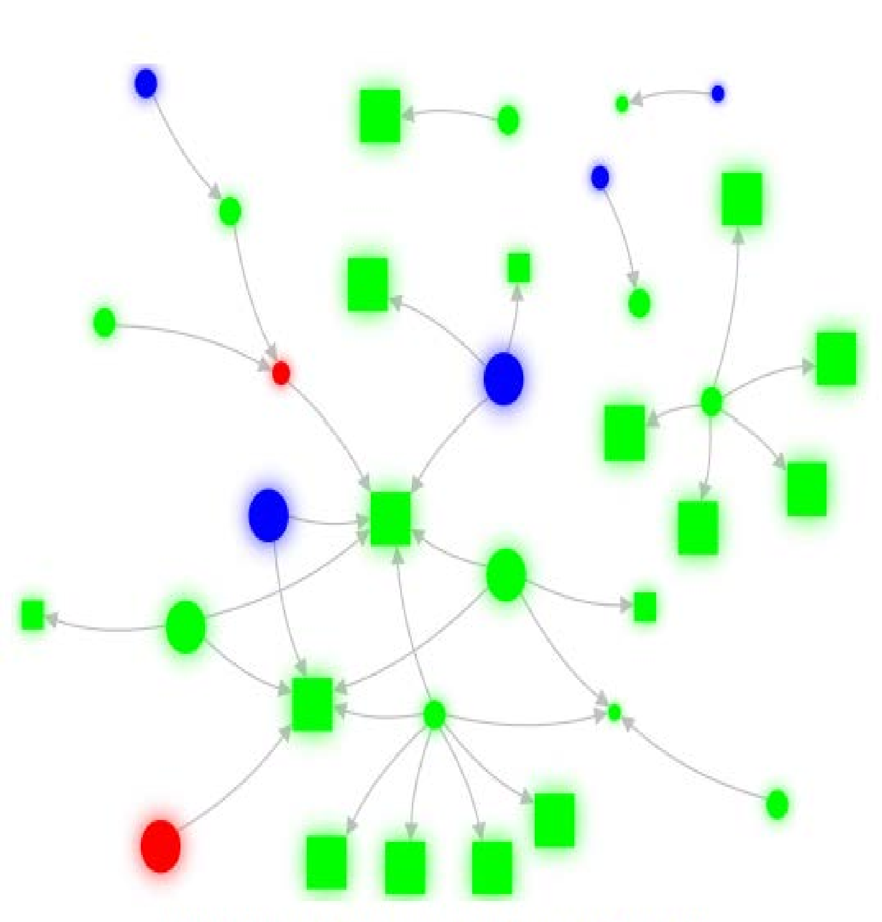
(b) Impact susceptibility of non-large FIs

Figure 6: *Trajectory of the average impact susceptibility of large and non-large FIs for static snapshots of the financial network in different periods.*

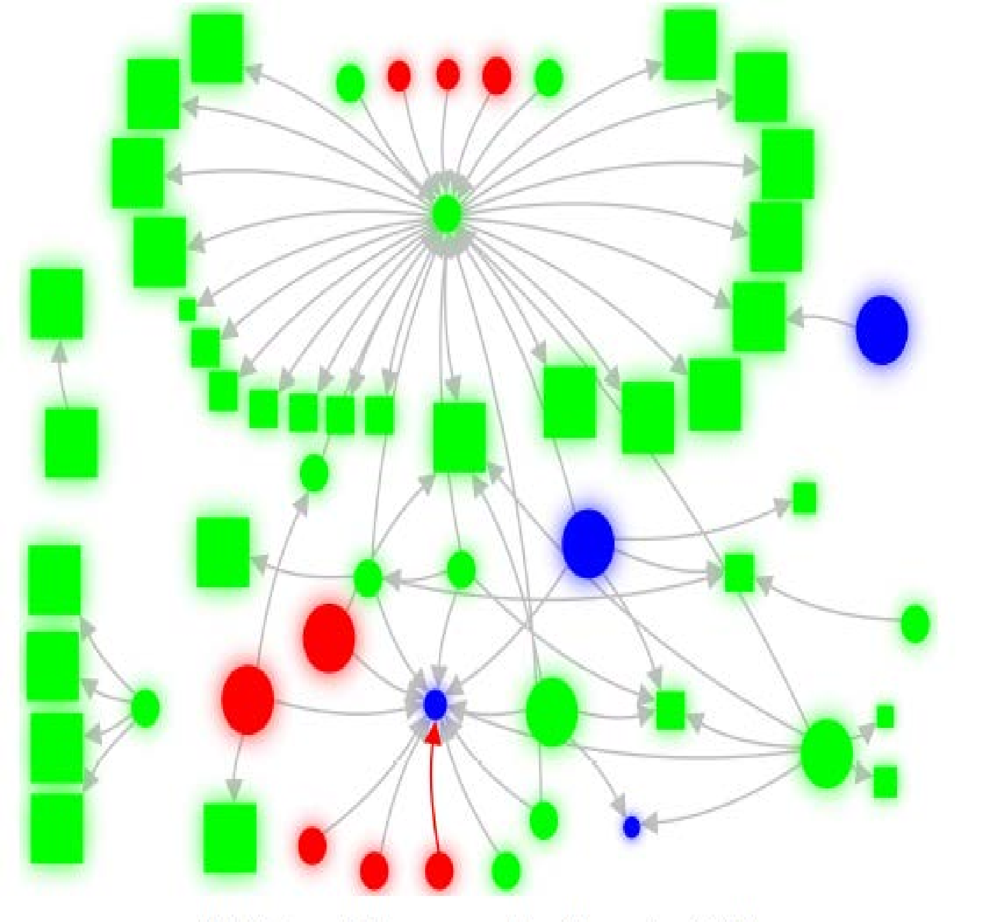
Vulnerability matrices

- Vulnerability networks of the Brazilian financial market computed for two dates.
- An edge from i to j exists if i’s default lead j to default as well.
- The circles denote banking institutions, while the squares, nonbanking institutions.
- The green color portrays domestic private institutions; the red color, government-owned institutions; the blue color, private with foreign control institutions; and the black color, private with foreign participation institutions.
- The vertices’ sizes are proportional to the corresponding institutions’ sizes.

Vulnerability Matrices



(a) Vulnerability network in September 2008



(b) Vulnerability network in December 2013

Impact Fluidity

- The potential impact fluidity in the network is given by:

$$F(\bar{\mathbf{V}}) = \frac{1}{N} \sum_{q \in \mathcal{V}} S_q(\bar{\mathbf{V}})$$

We quantify the potential fluidity in terms of average total impact susceptibility in the network.

- Domino-like effects due to a contagion process are more prone of happening in networks with high impact fluidity
- This holds true because, in this situation, FIs tend to be very susceptible to receiving impacts from the network due to their high communicability

Network Impact Fluidity

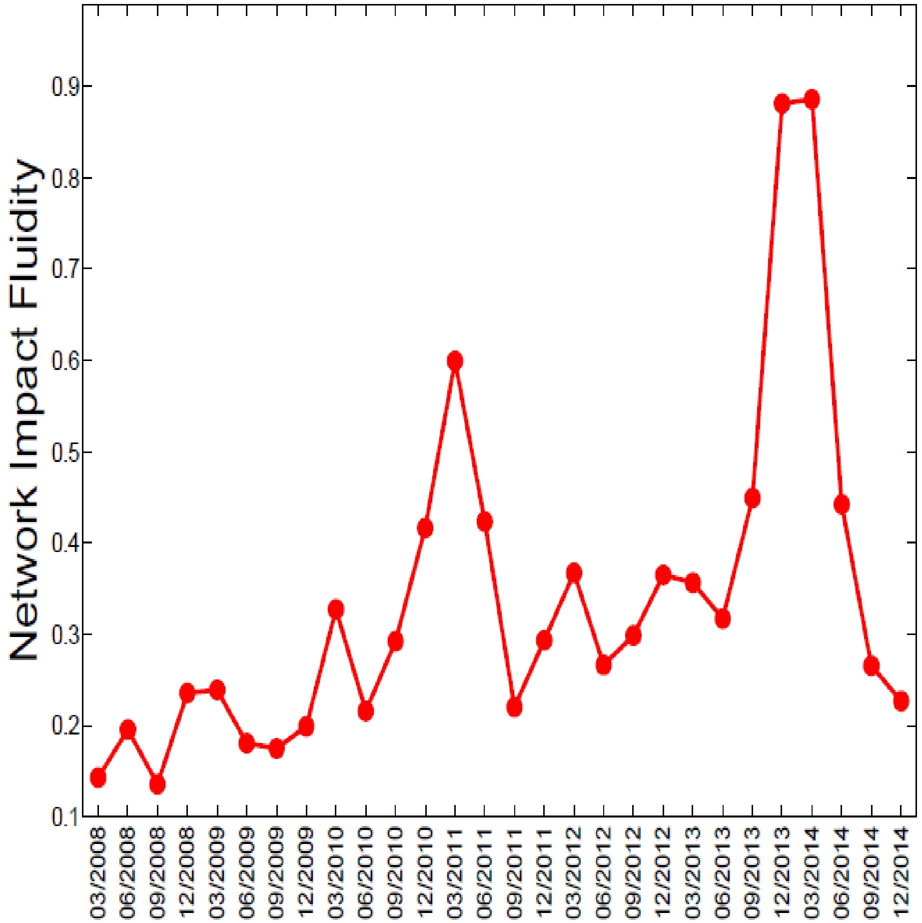
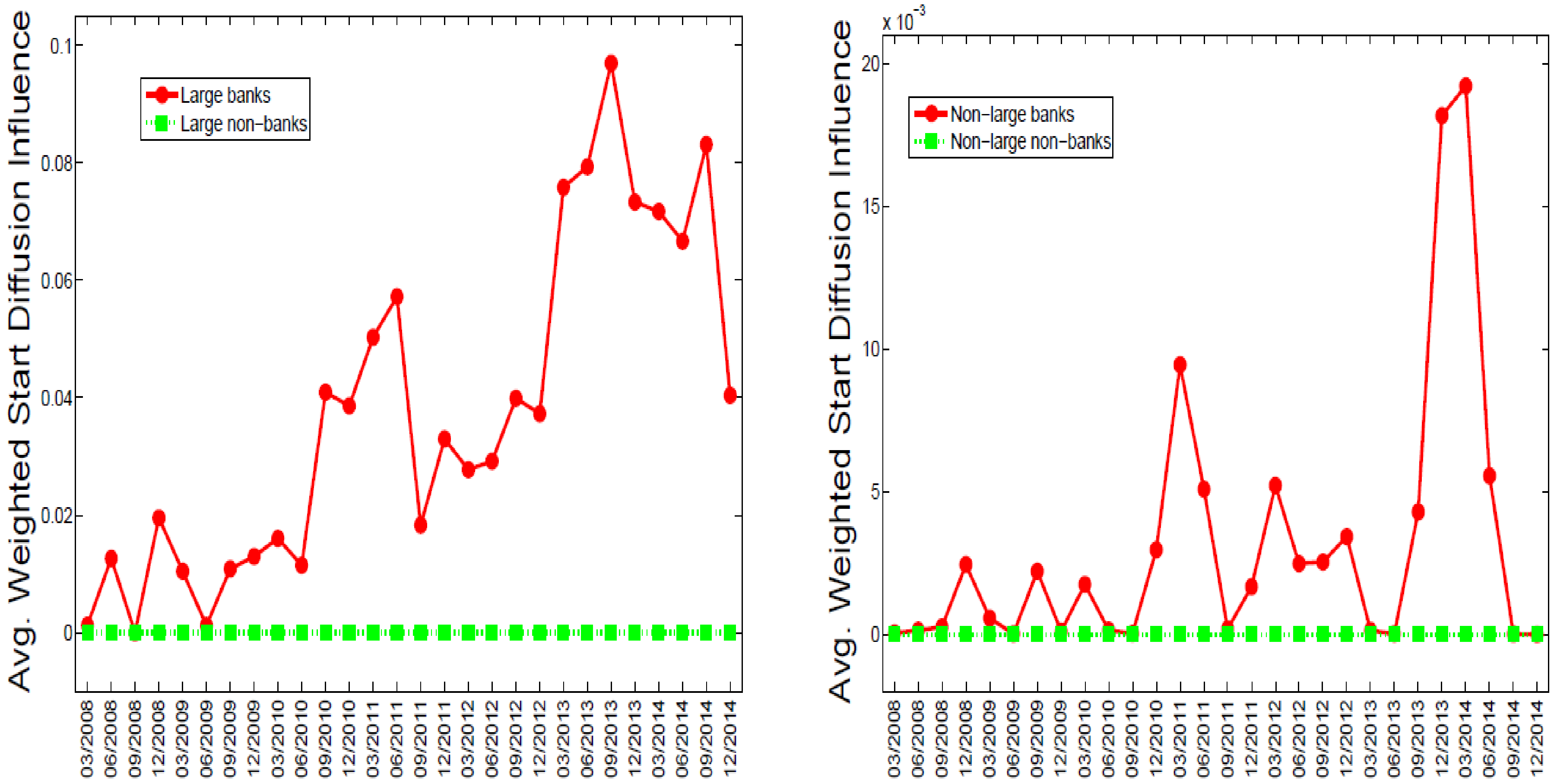


Figure 8: *Trajectory of the network impact fluidity for static snapshots of the financial network in different periods.*

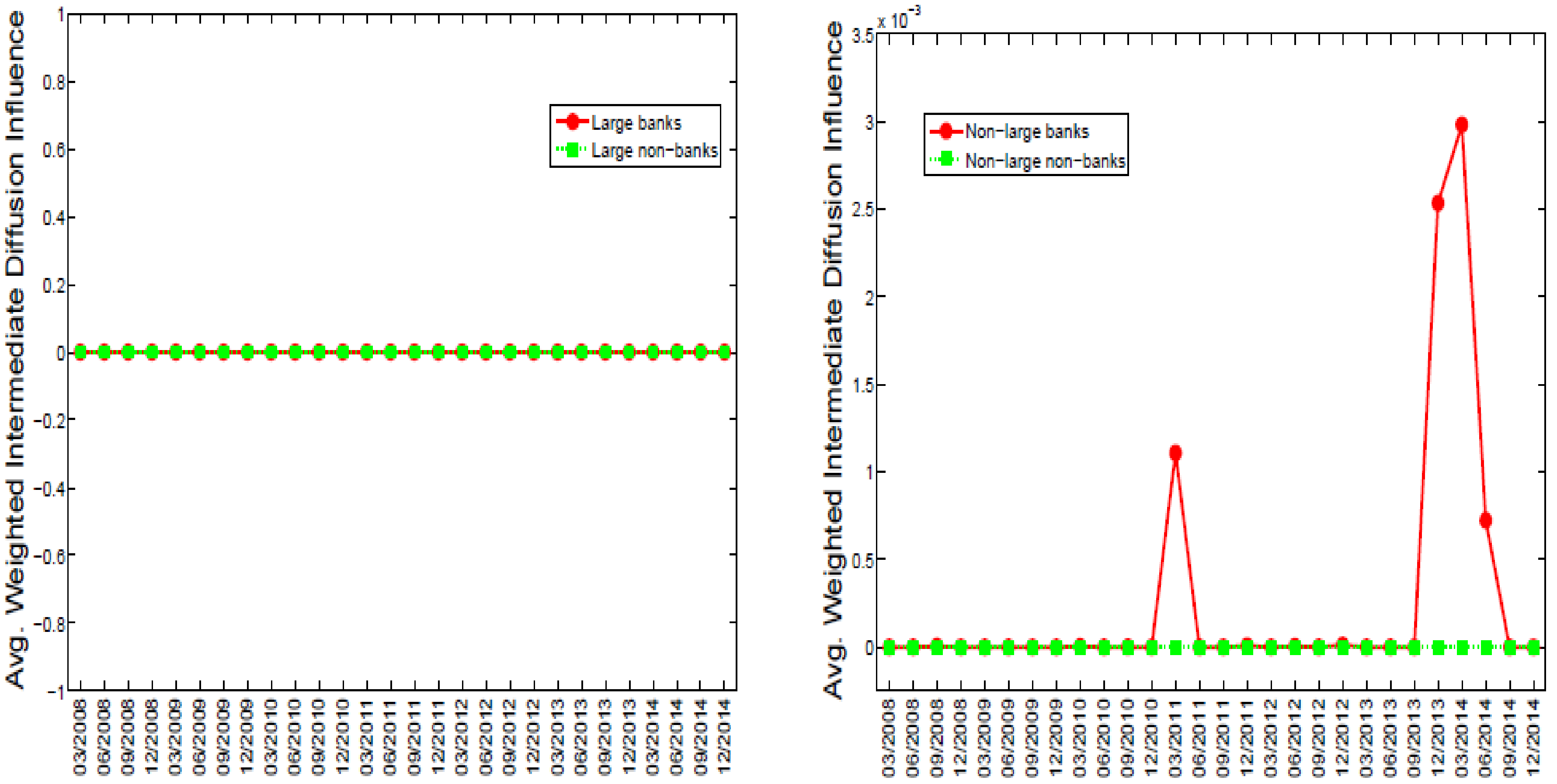
Weighted Start Impact Diffusion Influence



(a) Weighted start impact diffusion influence of large FIs

(b) Weighted start impact diffusion influence of non-large FIs

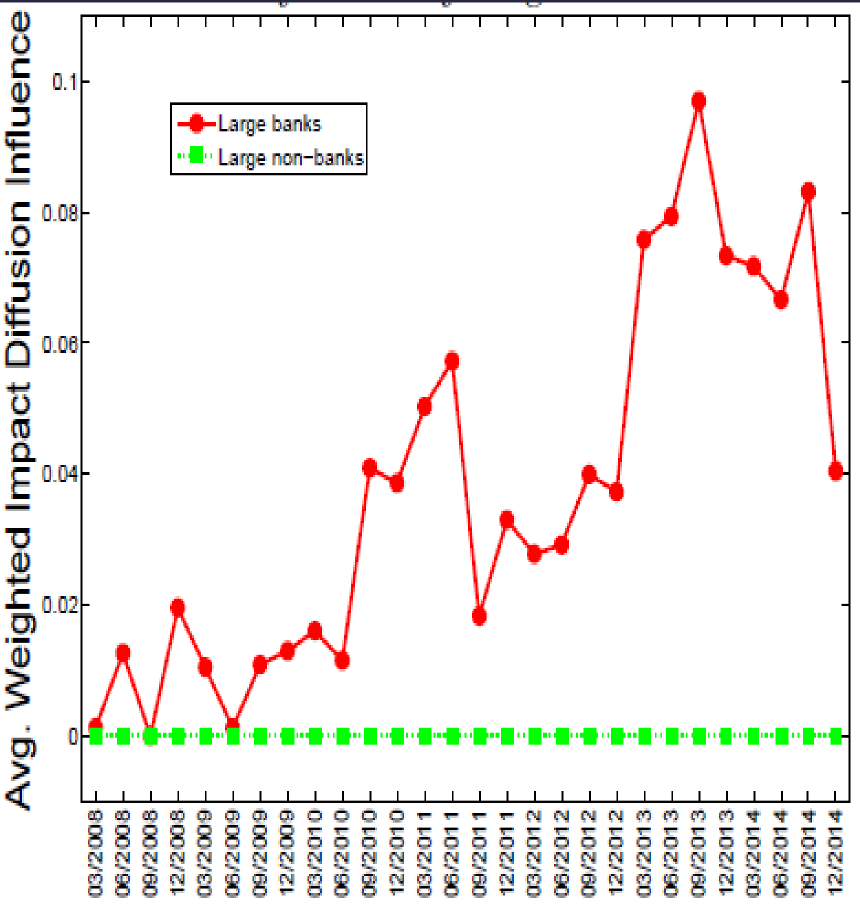
Weighted Intermediate Impact Diffusion Influence



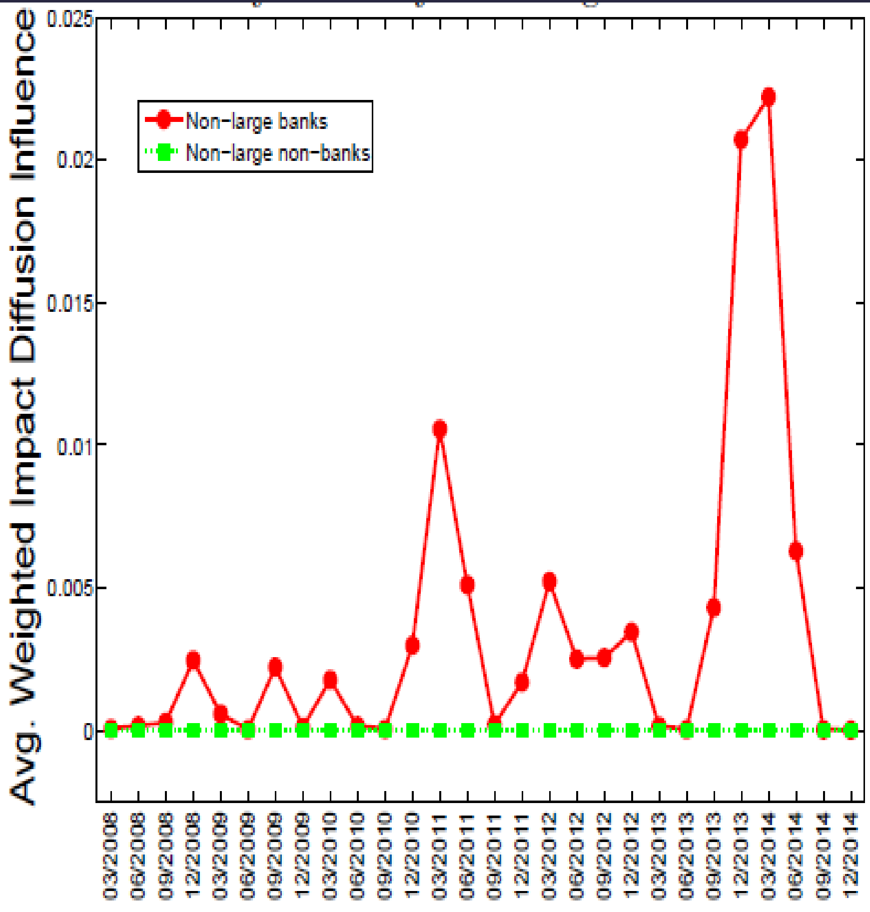
(c) Weighted intermediate impact diffusion influence of large FIs

(d) Weighted intermediate impact diffusion influence of non-large FIs

Total Weighted Impact Diffusion Influence



(e) Weighted impact diffusion influence of large FIs



(f) Weighted impact diffusion influence of non-large FIs

Most influential non-large vs large banks

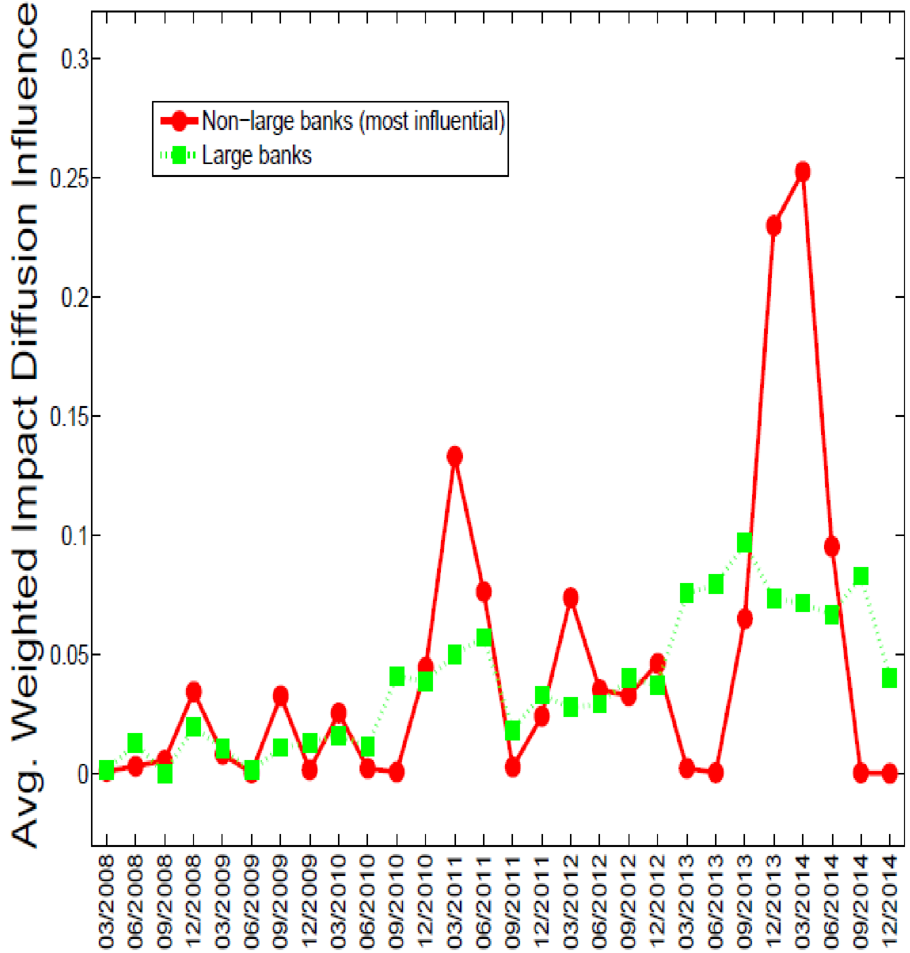


Figure 13: *Comparison of the average weighted impact diffusion influence of large banks and the top $M(t)$ non-large banks, where $M(t)$ is the number of large banks at instant t.*

Conclusions

- Potential good candidates for a close surveillance and additional capital requirements are those entities that are either:
  - **Remotely vulnerable ($S_q > 1$),** because distant defaults are likely to reach them – “weak banks” within the network

  or

  - **Remotely contagious ($I_q > 1$)**, because they can induce distant defaults – “too-central-to-fail” within the network

  or both

- Large non-bank institutions are relatively important within the network

Financial Regulation

- Financial Regulation – take into account financial network
- Financial network – is endogenous !
- Regulation - > rules that are endogenous in bank’s decision process
- Does it reduce Systemic Risk ? Not necessarily – network can be more vulnerable!

- Challenge: Modeling financial networks and bank regulation – interactions with the real economy.

Further research

- Multilayer networks
- Feedback-based systems – Financial Accelerator
- Link prediction and stress testing
- Financial Regulation and financial networks