Systemic Risk. Contagion

Application on the emerging market economies

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Introduction

- The recent and still ongoing economic and financial crisis has made clear the importance of methods of early detection of systemic risk in the financial system. In particular, researchers, regulators and policy-makers have recognized the importance of adopting a macroprodential approach to understand and mitigate financial stability.
- The traditional micro-prudential approach consists of trying and ensuring the stability of the banks, one by one, with the assumption that as long as each unit is safe, the system is safe. This approach has demonstrated to be a dangerous over - simplifying the situation.
- Indeed, we have learnt that it is precisely the interdependence among institutions, both in terms of liabilities or complex financial instruments and in terms of common exposure to asset classes, which leads to the emergence of systemic risk and makes the prediction of the behavior of financial systems so difficult.

Introduction (2)

- Interconnectedness, though, is now entering the debate on regulation: for example, the definition of "Global Systemically Important Banks" (G-SIBS, (Basel Committee on Banking Supervision, 2011)) does include the concept of interconnectedness, thereby measured as the aggregate value of assets and liabilities each bank has with respect to other banking institutions. Although this represents a fundamental step towards the inclusion of interconnectedness in assessing systemic risk, a further level of disaggregation would be needed.
- It is necessary the existence of an approach that stresses the systemic complexity of economic networks and that can be used to revise and extend established paradigms in economic theory. This will facilitate the design of policies that reduce conflicts between individual interests and global efficiency, as well as reduce the risk of global failure by making economic networks more robust.

Related literature

- Elsinger, H., Lehar, A., and Summer, M. (2006). Risk Assessment for Banking Systems.
- Gai, P., Haldane, A., and Kapadia, S. (2011). Complexity, concentration and contagion
- Bănulescu, G., Dumitrescu E., (2012) Which Are the SIFIs? A Component Expected Shortfall (CES) Approach to Systemic Risk
- Acharya, V. V., Engle, R. F. & Richardson, M. (2012) Capital Shortfall: A New Approach to Ranking and Regulating Systemic Risks
- Acemoglu, D., Ozdaglar, A., and Tahbaz-Salehi, A. (2013). Systemic Risk and Stability in Financial Networks
- Battiston, S., Caldarelli, G., D'Errico, M., Gurciullo, S. (2015) Leveraging the network: a stress-test framework based on DebtRank

Methodology (1) – *Network model*

- The network is based on the "fitness" model and attributes to every node a fitness level (x_i, a typically a proxy of its size in the interbank network)

- The probability that an exposure between nodes i and j exists is:
$$p_{ij} = \frac{z x_i x_j}{1 + z x_i x_j}$$

- The free-parameter z is obtaining if the total number of links is equal to the expected value of $\frac{1}{2} \sum_i \sum_{j \neq i} \frac{z x_i x_j}{1 + z x_i x_j}$

- Finally it is using a iterative proportional fitting algorithm on the interbank exposure matrix

Methodology (2) - *The stress-test*

- **First round: shock on external assets (non-interbank assets)**
- At t=1, a negative shock $r_k(1)$ reduces the value of the investment in external assets of bank i by the amount: $\sum_k r_k(1)\, A_{ik}^e(0)$

- The loss on the assets needs to be compensated by a corresponding reduction in equity

$$A_{ik}^e(0) - A_{ik}^e(1) = \sum_k r_k(1) A_{ik}^e(0) = E_i(0) - E_i(1)$$

where $A_{ik}^e(0)$ is the value of the kth element from the external assets for bank i at 0

- The individual and global (of the system) relative equity loss:
- $h_i(1) = min\left\{1, \frac{E_i(0)-E_i(1)}{E_i(0)}\right\} = min\{1, \sum_k l_{ik} r_k(1)\}$
- $H(1) = \sum_{i=1}^n w_i h_i(1)$
- $w_i = \frac{E_i(0)}{\sum_j E_j(0)}$

Methodology (3) - *The stress-test*

- **Second round: reverberation on the interbank network**

- Shocked banks from the first round transmit distress along the network, because the probability to repay its obligations decreased, so the market value of the obligations decrease
- The obligation for the banks that was previous shocked represents asset for the counterparty

- $h_i(2) = l_i^e r(1) + \sum_j l_{ij}^b l_j^e r(1)$
- $DR_k = \sum_i h_i(T) E_i(0)$

Methodology (3) - *The stress-test*

- **Third round and fire sales**
- Consider the leverage dynamics at t = 1, 2, … , T, T+1, T+2. The leverage at t is
- $l_i(t) = l_i^e(t) + l_i^b(t) = \frac{A_i^e(t)+A_i^b(t)}{E_i(t)}$
- The quantities of held assets are $Q(T\ +\ 1)$, unitary value of the external assets is the
- shock price $\hat{p} = p(1)$.
- $l_i(T+1) = \frac{A_i(T+1)}{E_i(T+1)} = \frac{(Q_i(0)+\Delta Q)\hat{p}+A_i^b(T)}{E_i(T+1)}$
- $\Delta Q_i\hat{p} + Q_i(0)\hat{p} + A_i^b(T) = l_i(T+1)E_i(T+1)$
- By setting the original (target) leverage $l_i(T+1) = l_i^* = l_i(0)$:

- $$\begin{aligned}\frac{\Delta Q_i}{Q_i(0)} &= \frac{1}{Q_i(0)\hat{p}}[l_i(0)E_i(T+1) - A_i(T+1)] \\ &= \frac{1}{Q_i(0)\hat{p}}\left[\frac{A_i(0)}{E_i(0)}E_i(T+1) - A_i(T+1)\right] \\ &= \frac{1}{Q_i(0)\hat{p}}\left[(1+\frac{\Delta E_i}{E_i(0)})A_i(0) - A_i(T+1)\right] \\ &= \frac{1}{Q_i(0)\hat{p}}\left[\left((1+\frac{\Delta E_i}{E_i(0)})(D_i(0)+E_i(0)\right) - (D_i(0) - E_i(T+1))\right] \\ &= \frac{1}{Q_i(0)\hat{p}}\left[\left((1+\frac{\Delta E_i}{E_i(0)})D_i(0)+E_i(0)\right) + \Delta E_i - D_i(0) - E_i(T+1))\right] \\ &= \frac{1}{Q_i(0)\hat{p}}\left[\frac{\Delta E_i}{E_i(0)}D_i(0)\right] = \frac{D_i(0)}{Q_i(0)\hat{p}}\frac{\Delta E_i}{E_i(0)}\end{aligned}$$

Methodology (4) - *The stress-test*

- Keeping in mind that the loss on equity is so far the one incurred at the end of the second round, i.e. $\frac{\Delta E_i}{E_i(0)} = l_i^e(0)r(1) + \sum_j l_{ij}^b l_j^e r(1)$

- At this point it is assumed that the impact of sales on the price of the asset is linear

$$\frac{p(T+2)-p(1)}{p(1)} = r(T+2) = \eta \frac{\Delta Q_i}{Q_i(0)} = \eta \frac{D_i(0)}{Q_i(0)\hat{p}} \frac{\Delta E_i}{E_i}$$

- $h_i(T+2) = r(1)(l_i^e + \sum_j l_{ij}^b l_j^e + \eta \frac{D_i(0)}{Q_i(0)\hat{p}} (l_i^e)^2)$

Methodology (5) - *The stress-test*

- **Loss distribution**
- The distress process allows to capture, at each time t the relative equity loss for both the individual institution and the system as a whole. This implies the possibility to compute, at each time t, a (continuous) relative equity loss distribution conditional to a certain shock.
- $VaR_i^{\alpha}(t) = \{x \in [0,1]: P(h_i(t) \leq x) = (1-\alpha)\}$
- $CVaR_i^{\alpha}(t) = \mathbb{E}[h_i(t) | h_i(t) \geq VaR_i^{\alpha}(t)]$
- $VaR_{system}^{\alpha}(t) = \{x \in [0,1]: P(H(t) \leq x) = (1-\alpha)\}$
- $CVaR_{system}^{\alpha}(t) = \mathbb{E}\left[H(t) | H(t) \geq VaR_{system}^{\alpha}(t)\right]$

Methodology (6) - *The Expected Shortfall*

- The Expected Shortfall
- ES (Expected Shortfall) i.e. the expected market loss conditional on the return being less than the distress event, the α quantile, i.e. the VAR, (or less than a threshold C, in a more general case) is given by
- $ES_{m,t}(C) = \mathbb{E}_{t-1}(r_{mt}|r_{mt} < C) = \sum_{i=1}^{N} w_{it}\mathbb{E}_{t-1}(r_{it}|r_{mt} < C)$
- where $r_{mt} = \sum_{i=1}^{n} w_{it}r_{it}$

- The Marginal Expected Shortfall
- MES measures the marginal contribution of a firm to the risk of the system by indicating the modification in ES engendered by a unit increase in the weight corresponding to the ith institution
- $MES_{it}(C) = \frac{\partial ES_{m,t}(C)}{\partial w_{it}} = \mathbb{E}_{t-1}(r_{it}|r_{mt} < C)$

Methodology (7) - *The Component Expected Shortfall*

- CES measures the absolute contribution of a firm to the risk of the financial system (as opposed to the marginal contribution).
- $CES_{it} = w_{it} \frac{\partial ES_{m,t-1}(C)}{\partial w_{it}}$
- $ES_{m,t}(C) = \sum_{i=1}^{n} CES_{it}(C)$

- $CES\%_{it}(C) = \frac{CES_{it}(C)}{\sum_{i=1}^{n} CES_{it}(C)} \times 100$

$$= \frac{w_{it}\mathbb{E}_t(r_{it}|r_{mt}<C)}{\sum_{i=1}^{n} w_{it}\mathbb{E}_t(r_{it}|r_{mt}<C)} \times 100$$

Methodology (8) - *The Component Expected Shortfall*

- From a bivariate GARCH process for the price returns:
- $r_t = H^{1/2} v_t$
- Where: $r_t{}' = (r_{mt}\, r_{it})$ represents the vector that contains market returns and bank's returns
- $v_t' = (\varepsilon_{mt} \xi_{it})$ represents the *i.i.d.* random vector
- H_t is the variance-covarince matrix, estimated with a DCC GARCH process

- $H_t = \begin{pmatrix} \sigma_{mt}^2 & \rho_{it}\sigma_{mt}\sigma_{it} \\ \rho_{it}\sigma_{mt}\sigma_{it} & \sigma_{it}^2 \end{pmatrix}$

- From Cholesky decomposition of the variance-covariance matrix H_t:

- $H_t^{1/2} = \begin{pmatrix} \sigma_{mt} & \sigma_{it}\rho_{it} \\ 0 & \sigma_{it}\sqrt{1-\sigma_{it}^2} \end{pmatrix}$

Methodology (9) - *The Component Expected Shortfall*

- To compute the CES (relying on the market model, as in the theoretical setup of Brownlees and Engle (2011))
- $r_{mt} = \sigma_{mt}\varepsilon_{mt}$
- $r_{it} = \sigma_{it}\rho_{it}\varepsilon_{mt} + \sigma_{it}\sqrt{1-\rho_{it}^2}\xi_{it}$
- where σ_{mt} and σ_{it} are the conditional standard deviations for the system and the firm, respectively, and the shocks ε_{mt} and ξ_{it} are independently and identically distributed with zero mean and identity covariance matrix.

Methodology (10) - *The Component Expected Shortfall*

- It follows that CES is given by a combination of volatility, correlation, conditional expectations of the standardized innovations distribution and size of the firm.

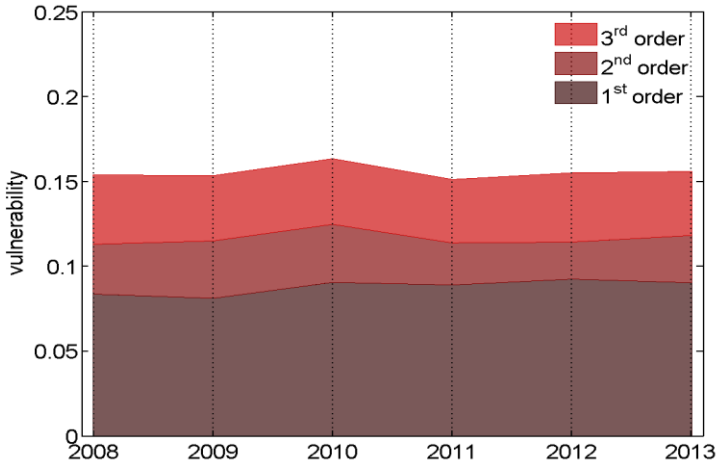
- $$CES_{it}(C) = w_{it}[\sigma_{it}\rho_{it}\mathbb{E}_t\left(\varepsilon_{mt}\middle|\varepsilon_{mt} < \frac{C}{\sigma_{mt}}\right) + \sigma_{it}\sqrt{1-\rho_{it}^2}\mathbb{E}_{t-1}\left(\xi_{it}\middle|\varepsilon_{mt} < \frac{C}{\sigma_{mt}}\right)]$$

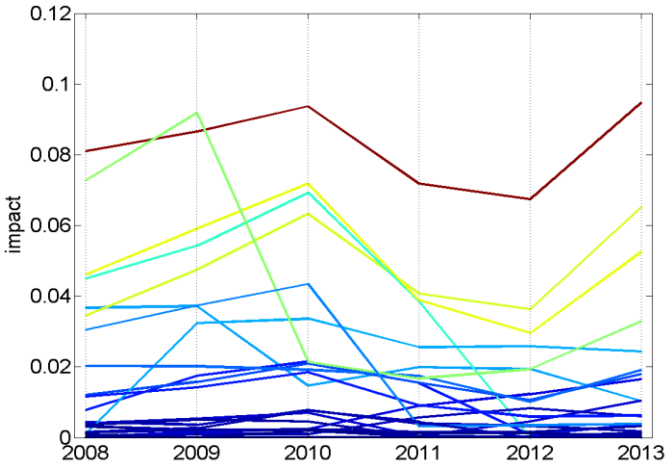
Data

- The dataset for the network model and distress is associated to 23 Romanian financial institutions. Data on assets, liabilities and capital is obtained from 2008Q4-2013Q4 financial reports. Source: *Bureau Van Dijk Bankscope*
- The dataset for Component Expected Shortfall model is associated from financial institutions that are publicly listed in Poland, Bulgaria, Hungary and Romania. Source: *Thomson Reuters Eikon Datastream*
- The dataset covers the period between January 2, 2007 and December 30, 2013 and is referring at the stock prices with daily frequency, number of shares outstanding.
- The returns series of the financial system includes only banks that are subject to my analysis
- $r_{mt} = \sum_{i=1}^{n} \frac{W_{t-1}^{i} r_{it}}{\sum_{j=1}^{n} W_{t-1}^{j}}$

Results (1)

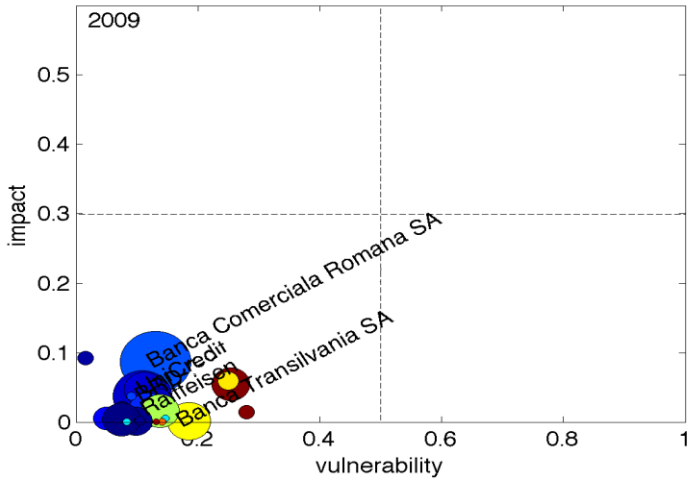
- The evolution of the vulnerability of the system shows that its relative losses in equity caused by the second and third round are substantial, suggesting that systemic risk researches based on first round effects produce an underestimation of potential losses.
- Moreover the impact of the banks tends to be persistent over time: the banks that have a high impact tend to remain high impactful compared with other over the years.

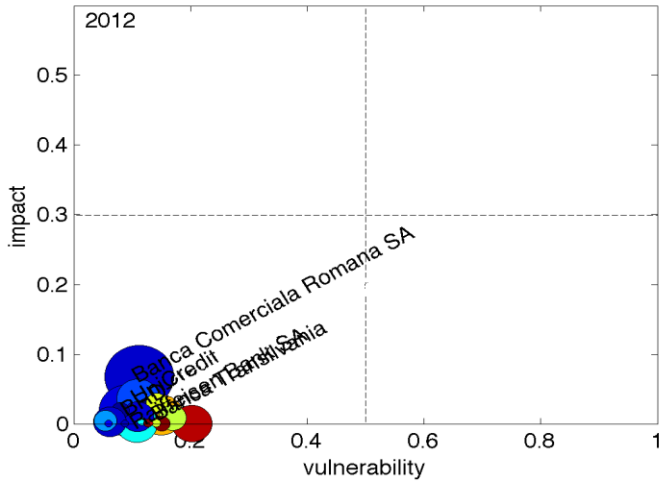




Results (2)

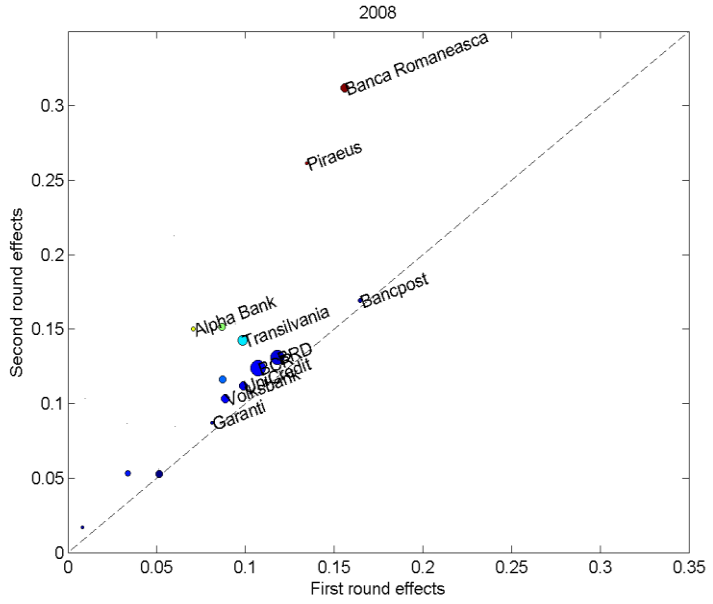
- The Romanian banks fit for the all analyzed years in the category *low vulnerability and low impact* and I didn't find institutions that are both highly vulnerable (up to their default) and impactful, so their systemic relevance isn't therefore extremely high, as they have higher likelihood to receive distress.

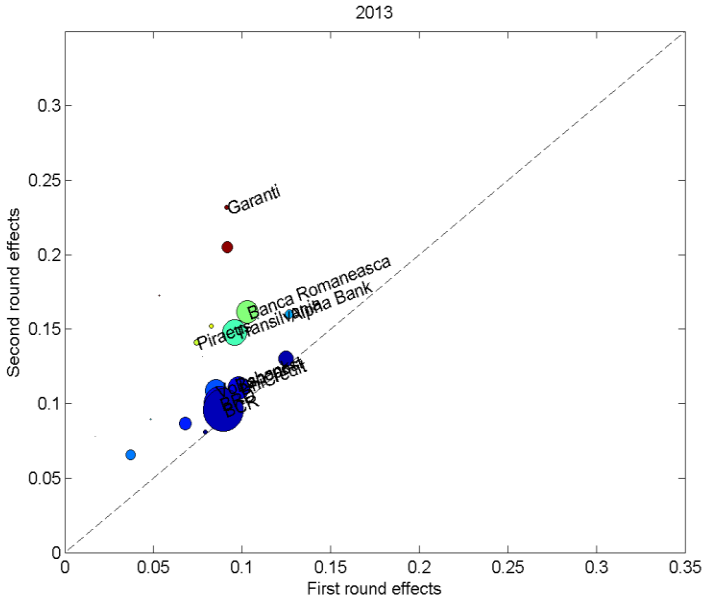




Results (3)

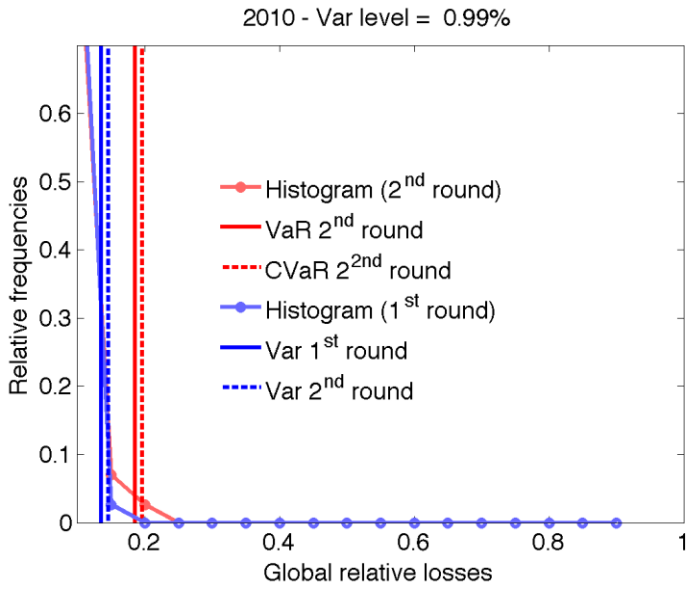
- The banks with Greeks capital present a higher vulnerability in 2008 (Piraeus, Romanian Bank), that shows the fact that they have big levels for interbank claims. Despite that, most of the banks have low levels for vulnerabilities; the biggest is about 0.3 for Romanian Bank.





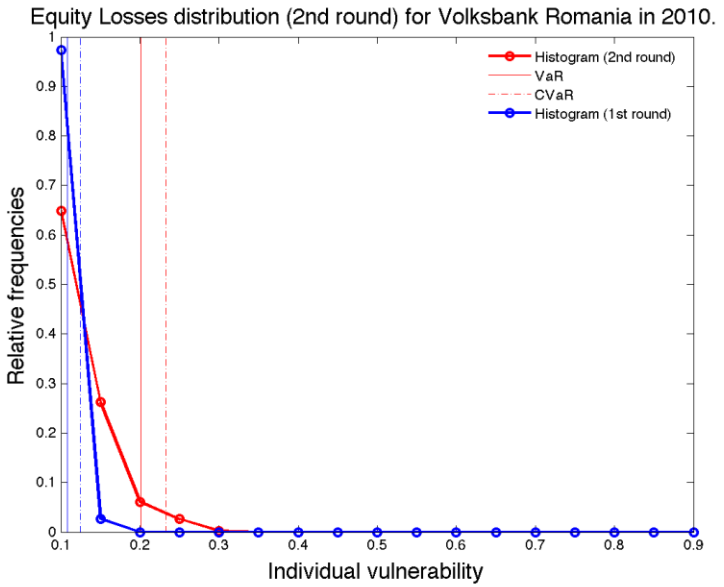
Results (4)

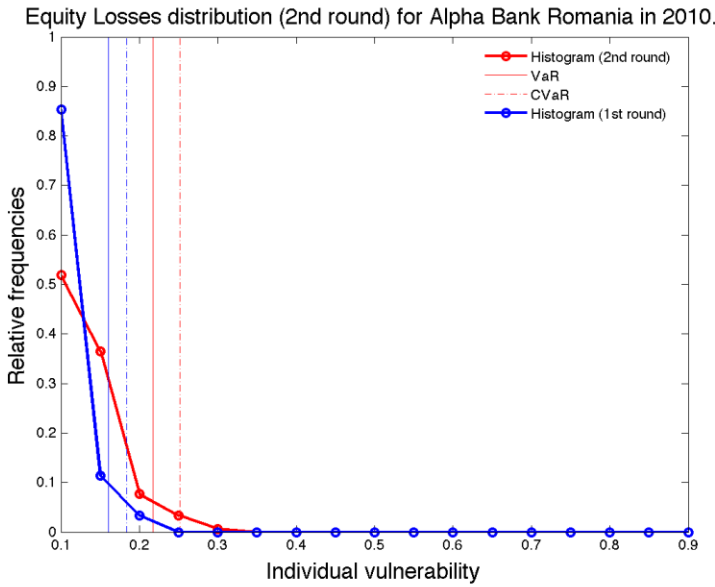
- It can be noted that the VaR for the second round, even in the year in which Romania was in the crisis apogee is at a low level, at about 20%. In other words, the Romanian banking system had in 2010 a maximum equity loss of 20% with a probability of 99%.



Results (5)

- I focused on the individual losses of Volksbank and Alpha Bank in 2010 because these are comparable regarding the asset size. Figures show that the distance to VaR in the second round is 0.21 compared to 0.18 in the first round and for CVaR is 0.25 in the second round. Volksbank presents a better situation and had a maximum loss of the equity of about 0.11 in the first and 20% in the second round.





Results (6)

- The most systemically important institution is OTP Bank, with a daily shortfall at the end of the period of 4.68%, conditional on the event that the return being less than the distress event, the 5% quantile, i.e. VaR, situation in which is defined the existence of a systemic event.

Rank	Bank	MES
1	OTP Bank	4.68%
2	FHB Mortgage	1.98%
3	Getin Holding	0.91%

Table: Ranks for the most risky institutions according to MES

Results (7)

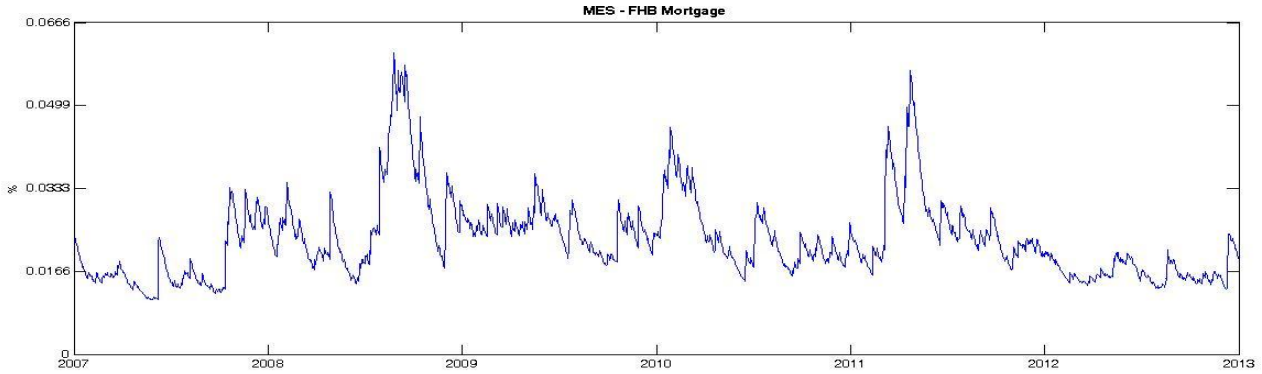
- OTP presents the higher risk from the sample and seems to dominate the market from this perspective because 97.7% of the total loss can be attributed to it at December 30, 2013.
- The CES measure decomposes the risk of the system in components, attached every bank and MES shows the sensitivity of the system's risk to a variation with 1 pp. of the share of the market capitalization of the component in the system. This imposes that the value for both to be different, so the rank can be different, but the trend is similar.

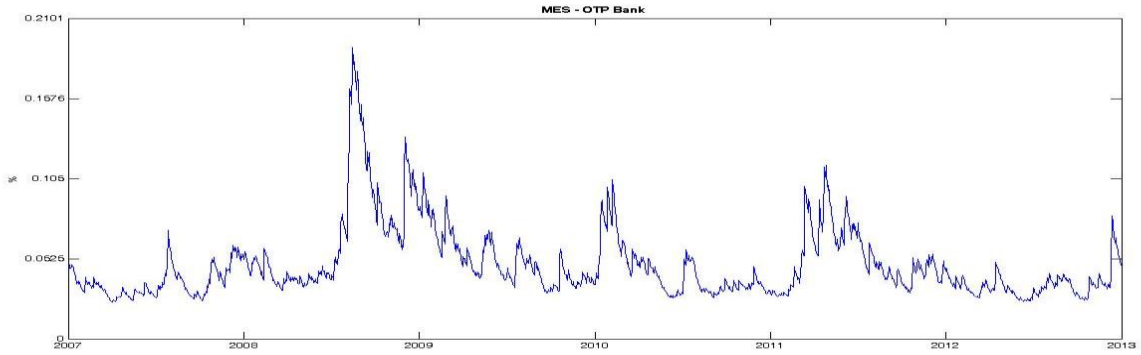
Rank	Bank	CES	CES(%)
1	OTP Bank	0.0377	97.7%
2	Komercni Banka	0.0005	1.2%
3	HFB Mortgage	0.0003	0.7%

Table: Ranks for the most risky institutions according to CES and CES(%)

Results (8)

- It can be observed that financial institutions have a similar trend in time but the magnitude of the measure is different





Results (9)

- Regarding the evolution in time of the CES, I observed that in pre-crisis period the values are low, high values for crisis period and from 2009, the risk starts to slowly decrease at a comparable level with the one recorded in the pre-crises period; these results can suggest that banks entered in a recovery period.

	2007	2008	2009	2010	2011	2012	2013
OTP Bank Nyrt	0.037241	0.08538	0.048036	0.022535	0.072668	0.024324	0.037663
Komercni Banka	0.000289	0.002178	0.000462	0.000368	0.000936	0.00054	0.000451
FHB Jelzalogbank Nyr	0.000767	0.002506	0.001236	0.00071	0.001036	0.0004	0.000271

Table: Evolution of the first 3 risky institutions according to CES

Concluding remarks (1)

- I didn't find institutions that are both highly vulnerable (up to their default) and impactful, so their systemic relevance isn't therefore extremely high, as they have higher likelihood to receive distress.
- Romanian financial institutions are far from default and low impactful (less than 10% of the initial equity). A financial institution that can cause a relative decrease of the system's equity of 10% still acts as a source of systemic risk and should not be ignored. In Romania, banks are below 10%, which makes the systemic relevance of banks in Romania to be low.
- The banks with Greeks capital present a higher vulnerability in 2008 (Piraeus, Romanian Bank), showing the fact that banks have big levels for interbank claims.
- It can be noted that the VaR for the second round, even in the year in which Romania was in the crisis apogee is at a low level, about 20%. In other words, the Romanian banking system had in 2010 a maximum equity loss of 20% with a probability of 99%.

Concluding remarks (2)

- The first round is the round in which is recorded the highest vulnerability, fact explicable by the big dimensions of the external leverage comparted to the interbank leverage.
- Regarding the CES and MES, the results are different because CES take into account the share of the market capital in the total market value of the system. However, in top 3 systemically important institutions, OTP was found both by MES and CES and the same thing for FHB.
- Moreover, MES model is not a very reliable tool for measuring systemic risk associated to a bank because of the existence of a strong correlation with the systematic (Beta), providing similar rankings.
- For the regulators, these measures must be accompanied by other models for a better view of the systemic risk in order to regulate the capital requirements for banks.
- There is no strong evidence that indicates the instability for the financial system or a future systemic crisis.

References

- Acemoglu, D., A. Ozdaglar, and A. Tahbaz-Salehi(2013),"Systemic Risk and Stability in Financial Networks".
- Acharya, V., L. Pedersen., T. Philippe, and M. Richardson (2010), "Measuring Systemic Risk", Department of Finance, NYU
- Battiston, S., M. Puliga., R. Kaushik., P. Tasca, and G. Caldarelli (2012),"DebtRank: Too Central to Fail? Financial Networks, the FED and Systemic Risk", 2, 541.
- Brownlees, T. C. and R. F. Engle (2011), "Volatility, Correlation and Tails for Systemic Risk measurement", *Working Paper*, NYU-Stern.
- Dumitrescu, E. and D. Banulescu (2015), "Which Are the SIFIs? A Component Expected Shortfall (CES) Approach to Systemic Risk", *Journal of Banking and Finance*.
- Gai, P., A. Haldane, and S. Kapadia (2011),"Complexity, concentration and contagion",*Journal of Monetary Economics*, 58(5), 453-470.
- Hurd, T. R. and J. P. Gleeson (2011),"A framework for analyzing contagion in banking networks

Thank You!