NBP Narodowy Bank Polski

Marcin Łupiński

Macroprudential tools of systemic risk analysis

Nottingham, 14 November 2014

Outline

Introduction

- The last financial crisis (2007-?) pointed out deficiencies in the policy-makers response to systemic risk
- Duality and complexity of systemic risk sources for small open emerging economies (SOEE):
  - Macroprudential level:
    - Expansionary domestic monetary or/and fiscal policy used to be a catalyst of excessive credit supply and permissive risk management policies that generate system-wide risks for financial system
    - Integration of global financial markets and deregulation of cross-border capital movements opens a gate for transmission of foreign macroeconomic policy shocks
  - Microprudential level:
    - Opaque and oligopolistic interconnections between large financial institutions amplify externalities stemming from excessive leverage and procyclical financial institutions business models
    - Broad group of the banks reacts in the very similar way to the external shocks (one-approach-fits-all) what is a source of inefficiency of the individual answers to the distress
- Risks tackling financial sector cannot be perceived as aggregations of individual institution's risks

Systemic risk analysis

- Filling key analytical gaps of the systemic risk analysis of the Polish banking sector:
  - Developing and improving National Bank of Poland's (NBP) systems of financial and prudential data collection to close systemic risk information gap
  - Designing analysis toolkit to support systemic risk identification, modelling and measurement in a forward-looking manner as a part of common stress-testing framework
- Using output of the analysis toolkit in the process of developing in cooperation with Polish Financial Supervisory Authority (FSA) fully-fledged national macroprudential policy framework:
  - To proactively detect shocks affecting Polish banking sector
  - To intervene as early as possible to reduce the impact of potential stresses on the whole Polish financial system

Closing data gaps

- Ensuring access to accurate and reliable financial and prudential statistics of Polish banking sector and Polish financial markets:
  - Measures of interconnections: gauging interlinkages among institutions (especially systemically important ones), sectors and countries,
  - Indicators of institutions and sectors cross-border dependencies and cross-border investment flows
  - Measures of common exposures and funding concentrations
  - Statistics of leverage
  - Measures financial markets risks (assets prices volatility)
  - Banks balance sheets data and ratios
  - Data on banks' collateral practices
  - Measures of maturity mismatches and financial imbalances
- Special attention paid to highly leveraged foreign investors on domestic capital markets (hedging funds, foreign bank's trading desks)

Developing systemic risk toolkit

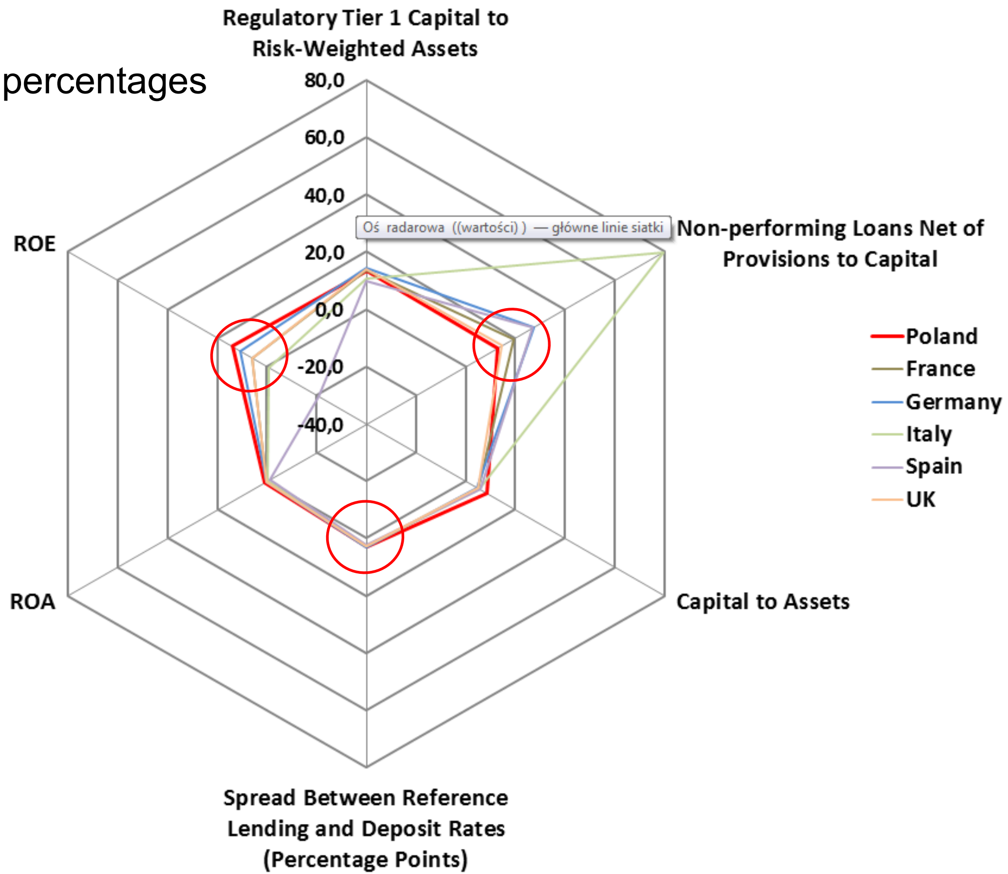
- Developing toolkit of systemic risk identification as a part of National Bank of Poland's common stress-testing framework
- Trying to integrate analysis of time and cross-sectional nature of systemic risk:
  - Time dimension: addressing evolution of system-wide risk over time taking into account risk stemming from banking sector procyclicality, amplifications of credit action, assets prices bubbles, excessive leverage and maturity mismatches
  - Cross-sectional dimension: addressing distribution of risk in the financial system at a certain point of time analysing risk concentrations caused with similarity of banking sector institutions' exposures of the and direct balance and off-balance sheet interlinkages among banks

From the results of the analysis to policy making

- Output of the NBP’s analysis toolkit used to conduct macroprudentially motivated interventions of Polish Financial Supervisory Authority in the inter-agency cooperation.
- NBP’s expertise to provide background for FSA recommendations restraining activities with extraordinary returns: e.g. caps on LtV and LtI/DtI ratios in mortgage lending
- Polish FSA direct interventions when particular bank breaches capital or liquidity requirements, when it aggressively increases its appetite on particular risk type or engages too much in cross-currency founding
- Close cooperation of National Bank of Poland and Financial Supervisory Authority strongly required as application of macroprudential instruments influences the monetary policy transmission mechanism. Ongoing initiative to institutionalize inter-agency systemic risk management in Poland: plans of establishing Systemic Risk Council (National Bank of Poland, Financial Supervisory Authority, Ministry of Finance)
- Analytical background of Polish Systemic Risk Council: Division in the NBP’s Department of Statistics that in cooperation with academics and practitioners collects financial and prudential data related to systemic risk and provides research frameworks

Characteristics of the Polish banking sector

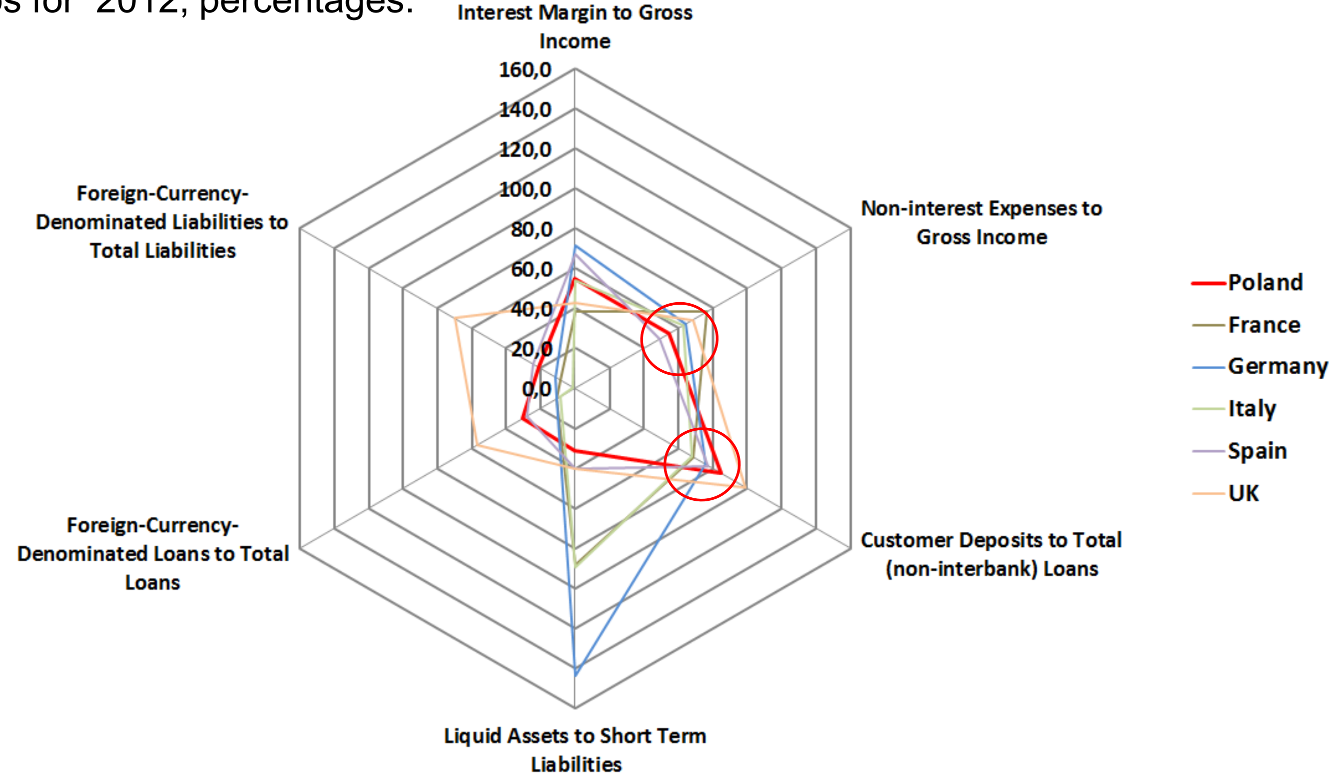
Key ratios for 2012, percentages



Sources: NBP and IMF's FSI database

Characteristics of the Polish banking sector con’t

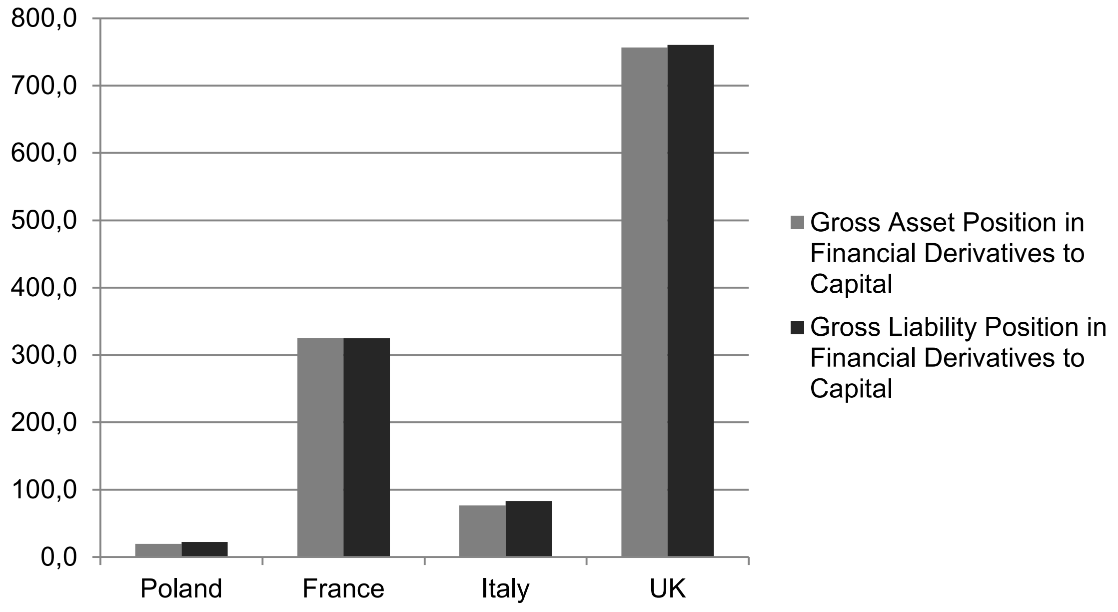
Key ratios for 2012, percentages:



Sources: NBP and IMF’s FSI database

Characteristics of the Polish banking sector con't

Key ratios for 2012, percentages:



Sources: NBP and IMF's FSI database

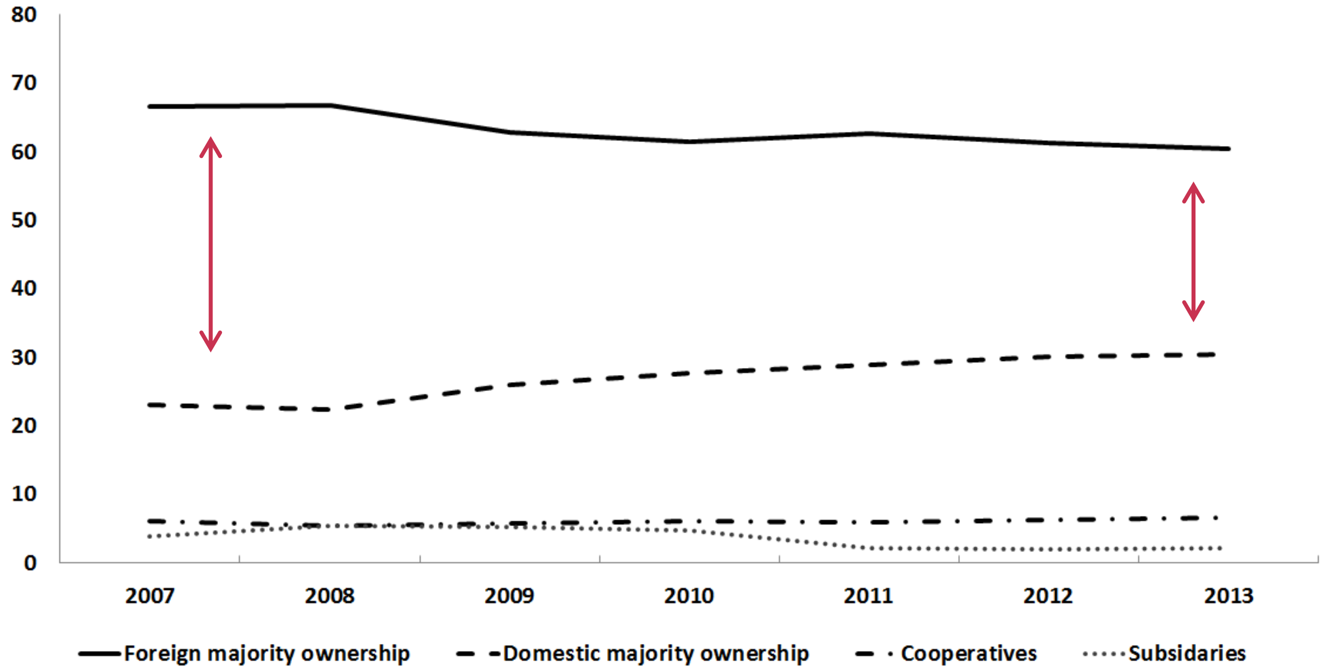
Polish Systemically Important Institutions

Bank Name	Country	Assets 31 Dec 2012 ($Mn)
HSBC Holdings	UK	2,671,318
BNP Paribas	FR	2,482,950
Credit Agricole	FR	2,353,553
Deutsche Bank	DE	2,222,620
Barclays	UK	2,161,889
Societe Generale	FR	1,703,809
Groupe BPCE	FR	1,549,682
Banco Santander	SP	1,538,811
Lloyds Banking Group	UK	1,395,436
…	…	…
PKO Bank Polski	PL	66,410
Bank Pekao (UniCredit S.p.A., 50.10%)	PL/IT	52,837
Bank Zachodni WBK (Banco Santander, 75.19%)	PL/SP	35,364

Sources: NBP and The Banker database

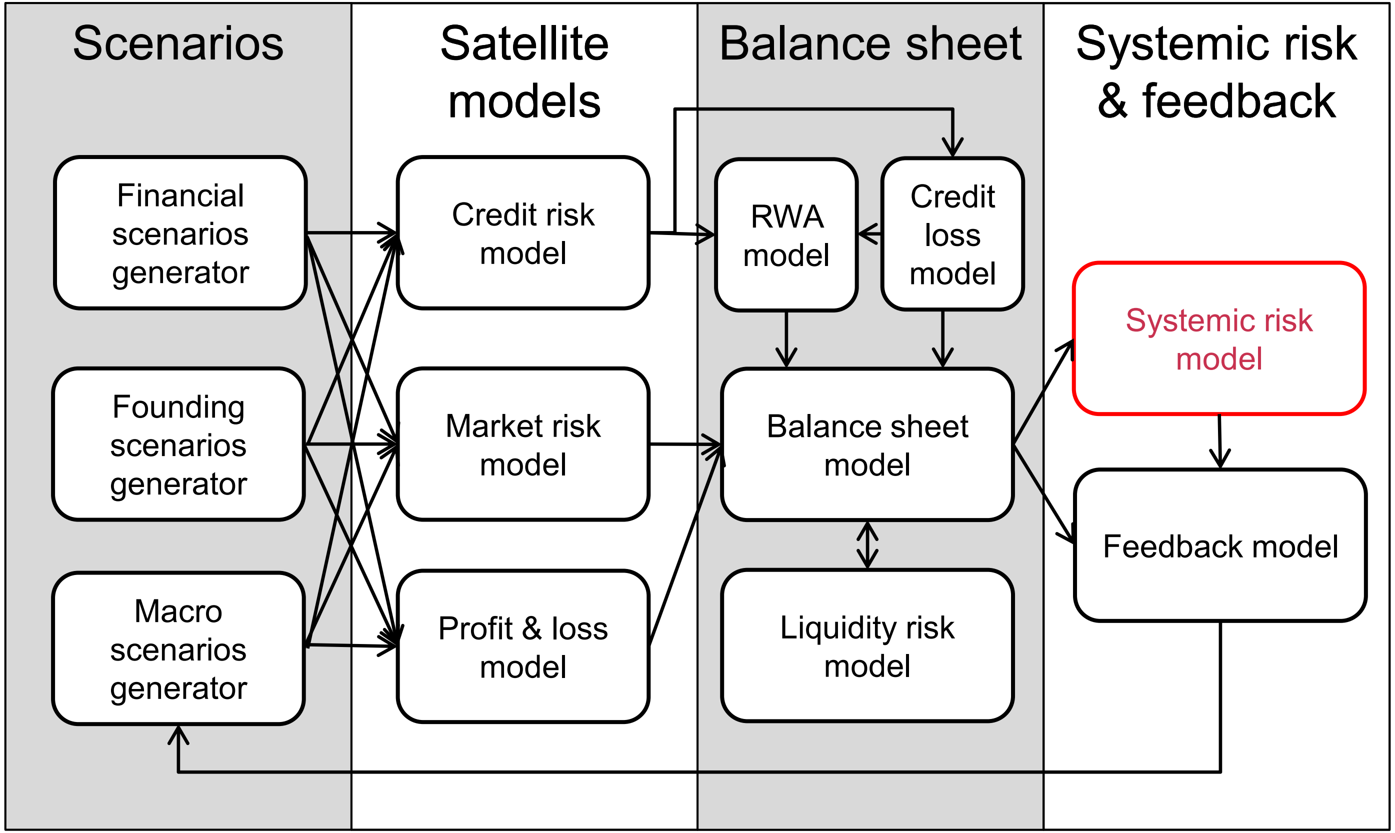
Importance of the ownership structure

Structure of ownership of domestic banks in Poland, percentage of total banking sector assets:



Source: NBP

National bank of Poland's stress testing framework



Alternative systemic risk models

- CoVaR
  - Augmentation of the well-known value-at-risk (VaR) approach to compute impact of SIFIs on other institutions of the sector
  - Conditional Value-at-Risk (CoVaR) of the bank *j* dependent on the risk generated by systemically important bank *i* at period *t:*

$$\Pr\left(AR_t^j \leq CoVaR_t^{j|i,k} \middle| AR_t^i = VaR_t^{i,k}\right) = k \quad (1)$$

  - AR_t^j represents return on assets of the institution *j:*

$$AR_t^j = \frac{AV_t^j - AV_{t-1}^j}{AV_{t-1}^j} \quad (2)$$

  - AV_t^j is a product of the market value of the institution *j* at time *t* and ratio of its assets book value to its total shares book value

$$AV_t^j = MV_t^j * ABVTSBVR_t^j \quad (3)$$

Alternative systemic risk models con't

- CoVaR con't
  - The risk impact of the institution *i* on institution *j* is calculated as:

$$\Delta CoVaR_t^{j|i,k} = CoVaR_t^{j|i,k} - CoVaR_t^{j|i,50\%} \tag{4}$$

  - $\Delta CoVaR_t^{j|i,k}$ distribution is dependent on the vector of risk factors (RF_t). Quintile regression for quintile k and median can be used to compute parameters of the equations:

$$AR_t^i = a^i + b^i RF_{t-1} + \varepsilon_t^i \tag{5}$$

$$AR_t^j = a^{j|i} + b^{j|i} AR_{t-1}^j + c^{j|i} RF_{t-1} + \varepsilon_t^{j|i}$$

  - The estimated parameters are then applied to estimate values of $VaR_t^{i,k}$ and $CoVaR_t^{j|i,k}$:

$$VaR_t^{i,k} = \hat{a}^{i,k} + \hat{b}^{i,k} RF_{t-1} \tag{6}$$

$$CoVaR_t^{j|i,k} = \hat{a}^{j|i,k} + \hat{b}^{j|i,k} VaR_t^{i,k} + \hat{c}^{j|i,k} RF_{t-1} \tag{7}$$

  - And finally:

$$\Delta CoVaR_t^{j|i,k} = \hat{b}^{j|i,k}(VaR_t^{j,k} - VaR_t^{j,50\%}) \tag{8}$$

Alternative systemic risk models con't

- Co-Risk
  - Dependencies among individual risk exposures of particular institutions are quantified with relations among their credit default swaps' prices
  - For particular *k* quintile of risk distribution, prices of the selected (indexed *j*) financial institution's CDS at period t are connected with analogous instrument of SIFI *i* with linear expression:

$$\mathrm{CDS}_t^{j,k} = a^{i,k} + b_i^{i,k}\,\mathrm{CDS}_t^{i,k} + c^{i,k}\,RF_{t-1} \quad (9)$$

  - Parameters of the above equation estimated for (*1-k*) tail percentile are used to compute measure of mutual systemic risk:

$$CoRisk_t^{j,i,95\%} = \left(\frac{\hat{a}^{i,95\%} + \hat{b}_i^{i,95\%}\,\mathrm{CDS}_t^{i,95\%} + \hat{c}^{i,95\%}\,RF_{t-1}}{\mathrm{CDS}_t^{i,95\%}} - 1\right) * 100\%, \quad (10)$$

Alternative systemic risk models con't

- SES (Systemic Expected Shortfall)
  - Analysis of the SIFI's expected loss distribution's tail. Combined value of bail-outs and losses is good empirical approximation of the systemic expected shortfall (SES) of particular banking sector
  - SES of SIFI's *i* depends linearly on its marginal expected shortfall *(MES)* and its leverage level *(LL)*:

$$\mathrm{SES}_t^i = a + b\, MES_t^i + cLL_t^i + \varepsilon_t^i \quad (11)$$

  - MES for institution indexed *i* at period t is defined as average return on shares during 5% of the days with recorded worst returns in the analysed history:

$$MES_t^i = \frac{\sum_{k:\text{indices of days of 5\% of the worst returns}} RS_k^i}{\text{number of days with 5\% of the worst returns}} \quad (12)$$

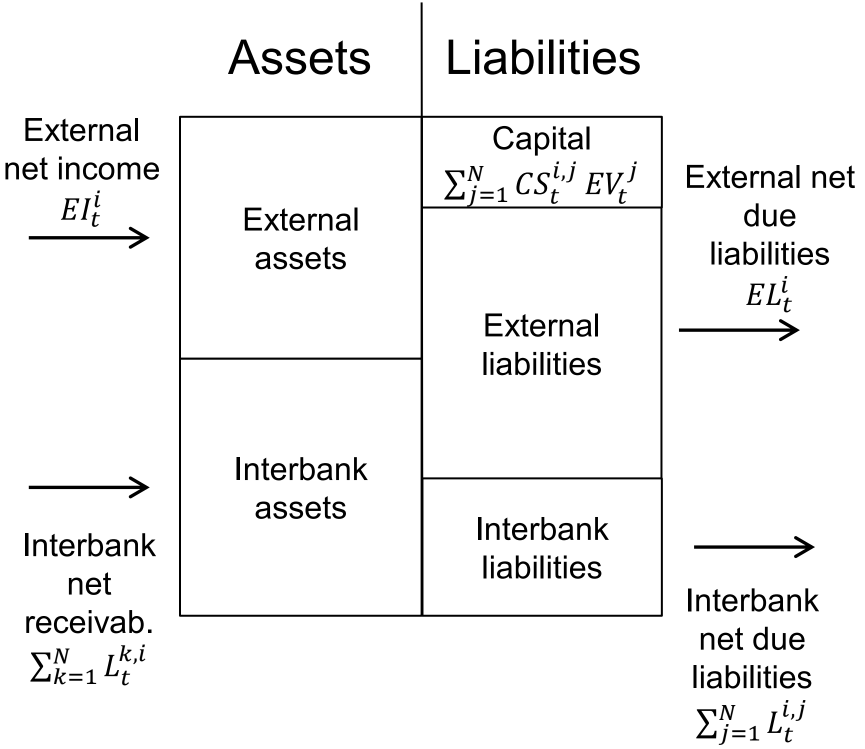
  - Finally systemic risk impact on the whole banking sector of the institution *i* (SR) can be approximated with formula

$$SR_t^i = \frac{\hat{b}}{\hat{b}+\hat{c}} MES_t^i + \frac{\hat{c}}{\hat{b}+\hat{c}} LL_t^i. \quad (13)$$

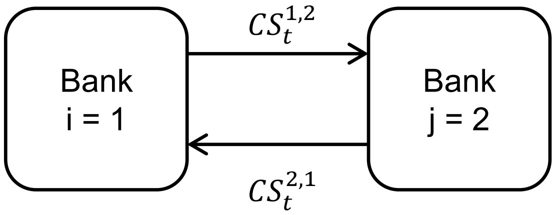
Network model

- Network model of systemic risk allows modelling direct relations among banking sector entities resulting from financial instruments exposures and structure of the capital
- Banking sector at period t consists on *N* entities (network nodes). Particular financial entity's *i* balance sheet at period *t* consists of:
  - Liabilities:
    - Aggregated equity capital $\sum_{j=1}^{N} CS_t^{i,j} EV_t^j$ where $CS_t^{i,j}$ is fraction of share (range [0,1]) of the bank *j* belonging to the bank *i* ($CS_t^{i,i} \geq 0$) and EV_t^j is equity capital of the bank *j*
    - External liabilities with net due value EL_t^i
    - Interbank liabilities owed to the institution *j* with net due value $L_t^{i,j}$ ($L_t^{i,j} \geq 0$)
  - Assets:
    - External assets replenished with net income EI_t^i
    - Interbank assets replenished with net receivables from the institution *k* $L_t^{k,i}$ ($L_t^{k,i} \geq 0$)

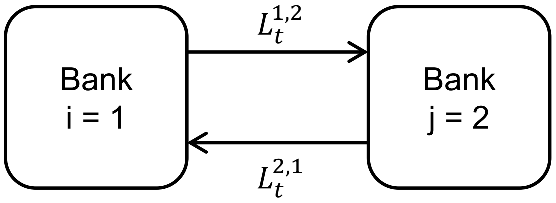
Network model con't



Capital channel:

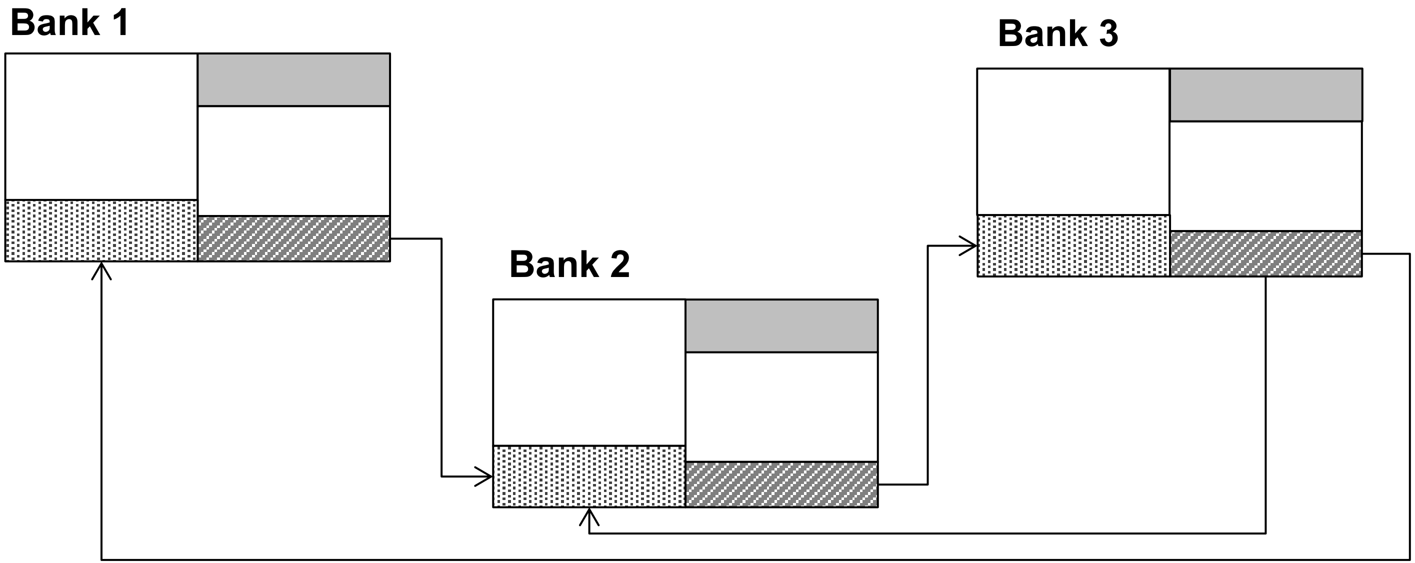


Interbank liabilities channel:



Network model con't

Banks' interlinkages network:



Network model con't

- Stream of supposed (contractual) payments of the bank *i* at period *t*:

$$P_t^i = \sum_{j=1}^{N} L_t^{i,j} + EL_t^i \tag{14}$$

- If bank *i* net exogenous income and receivables from other entities are not enough to cover its net due liabilities to other entities from the sector and outside, it pays its proportionally:

$$\Pi_t^{i,j} = \begin{cases} \frac{L_t^{i,j}}{P_t^i} \text{ if } P_t^i > 0 \\ 0 \quad \text{in the other case} \end{cases} \tag{15}$$

- Actual payments of the bank *i* at period *t*:

$$\mathrm{AP}_t^i = \begin{cases} P_t^i \text{ if } P_t^i \leq \sum_{k=1}^{N} L_t^{k,i} + EI_t^i \\ \sum_{k=1}^{N} L_t^{k,i} + EI_t^i \text{ in the other case} \end{cases} \tag{16}$$

Network model con’t

- Values of capital shares at period *t* ($CS_t^{i,j}$) are stored in matrix CS_t *(NxN)*
- Value of banks’ equity capital at period *t* (EV_t^i) are stored in a vector EV_t*(Nx1)*
- Mutual net due liabilities ($L_t^{i,j}$) of the banking sector entities at period *t* are gathered in a matrix (L_t) *(NxN)*
- Value of banks’ external income at period *t* (EI_t^i) are stored in in a vector EI_t*(Nx1)*
- Value of banks’ external net due liabilities at period *t* (EL_t^i) are stored in in a vector EL_t*(Nx1)*
- Supposed due payments of the banks (P_t^i) are stored in vector P_t(*Nx1*)
- Proportional payments of the banks ($\Pi_t^{i,j}$) are stored in matrix Π_t(*NxN*)
- Actual payments of the banks at period *t* are stored in vector AP_t(*Nx1*)
- The model is defined with set of matrices/vectors $\{CS_t, EV_t, L_t, EI_t, EL_t\}$. At period *t* = 0 elements of the mentioned matrices’ set are calculated (or approximated) with help of prudential statistics
- Supposed due payments vector (P_t), proportional payments matrix (Π_t) and actual payments vector (AP_t) are derived from them

Network model con't

- For the above set of matrices a map of projection is constructed ($\vec{0}$ is a vector of nulls sized *Nx1*):

$$M\left(EI_t^i, \Pi_t, CS_t, EV_t^i, AP_t\right) = \left[EI_t^i + \Pi_t' AP_t - AP_t^i + CS_t EV_t^j\right] \vee \vec{0} \qquad (17)$$

- For a given vector of real payments AP_t exists one fixed point *M* corresponding to a vector of values of the share capital of particular banks ($\overline{EV(AP_t)}$ computed as:

$$\overline{EV_t(AP_t)} = \left[EI_t + \Pi_t' AP_t - AP_t + CS_t \overline{EV_t(AP_t)}\right] \vee \vec{0} \qquad (18)$$

- The selected fixed point corresponds to a vector of actual payments $\overline{AP_t}$, called also clearing payment vector

$$\overline{AP_t^i} = \begin{cases} 0 \text{ if } EI_t^i + \sum_{j=1}^{N}\left(\Pi_t^{i,j}\overline{AP_t^j} + CS_t^{i,j}\overline{EV_t^j\left(\overline{AP_t^j}\right)}\right) \le 0 \\ EI_t^i + \sum_{j=1}^{N}\left(\Pi_t^{i,j}\overline{AP_t^j} + CS_t^{i,j}\overline{EV_t^i\left(\overline{AP_t^j}\right)}\right) if\ 0 < EI_t^i + \sum_{j=1}^{N}\left(\Pi_t^{i,j}\overline{AP_t^j} + CS_t^{i,j}\overline{EV_t^j\left(\overline{AP_t^j}\right)}\right) < P_t^i. \\ P_t^i\ if\ P_t^i \le EI_t^i + \sum_{j=1}^{N}\left(\Pi_t^{i,j}\overline{AP_t^j} + CS_t^{i,j}\overline{EV_t^j\left(\overline{AP_t^j}\right)}\right) \end{cases} \qquad (19)$$

Network model con't

- Augmentations:
  - Idiosyncratic costs of the bankruptcy ($BC_t^i > 0$) with new definition of the clearing payments' vector:

$$\overline{AP_t^i} = \begin{cases} P_t^i \text{ if } P_t^i \leq EI_t^i + \sum_{j=1}^{N} \left(\Pi_t^{i,j} \overline{AP_t^j} + CS_t^{i,j} \overline{EVX_t^j\left(\overline{AP_t^j}\right)} \right) \\ \max\left(0, EI_t^i - BC_t^i + \sum_{j=1}^{N} \left(\Pi_t^{i,j} \overline{AP_t^j} + CS_t^{i,j} \overline{EVX_t^j\left(\overline{AP_t^j}\right)} \right) \right) \; in\ the\ o.c. \end{cases} \quad (20)$$

where $EVX\left(\overline{AP_t^j}\right)$ is modified vector of the values of share capital belonging to institution indexed *i* computed according to the following expression:

$$\overline{EVX_t^i\left(\overline{AP_t^i}\right)} = \begin{cases} EI_t^i - \overline{AP_t^i} + \sum_{j=1}^{N} \left(\Pi_t^{i,j} \overline{AP_t^j} + CS_t^{i,j} \overline{EVX_t^j\left(\overline{AP_t^j}\right)} \right) \text{ if } \overline{AP_t^j} = P_t^i \\ 0 \;\; in\ the \text{ other case} \end{cases} \quad (21)$$

Network model con't

- Augmentations:
  - Liabilities of the particular bank are characterized with different seniorities. The liabilities of the bank are classified with *SC* classes $\left(S_t^i = (1,2,\dots,SC^i)\right)$. Maximum number of seniority classes is given with $\overline{SC} = max_i\,(SC^i)$. The value of liabilities with seniority *s* possessed with bank *i* at period *t* equals to:

$$P_t^{i,s} = \sum_{j=1}^{N} L_t^{i,j,s} + EL_t^{i,s}\,, \qquad (22)$$

  - Elements of the proportional payments matrix Π_t^s are characterized with the expression:

$$\Pi_t^{i,j,s} = \begin{cases} \frac{L_t^{i,j,s}}{P_t^i} \text{ if } P_t^{i,s} > 0 \\ 0 \quad \mathit{in\ the} \text{ other case} \end{cases} \qquad (23)$$

Network model con't

- The augmented projection map for $AP_t^{\cdot,s} = \left(AP_t^{1,s}, AP_t^{2,s}, \ldots, AP_t^{N,s}\right)'$

$$M\left(EI_t^i, \Pi_t^s, CS_t, EV_t^i, AP_t^{\cdot,s}\right) = \left[EI_t^i + \sum_{s=1}^{\overline{SC}} \Pi_t' AP_t^{\cdot,s} - \sum_{s=1}^{\overline{SC}} P_t^{\cdot,s} + CS_t EV_t^j\right] \vee \vec{0} \quad (24)$$

- Vector of the clearing payments $S \in \{1,2,\ldots,\overline{SC}\}$ is written as:

$$\overline{AP_t^{i,S}} = \min\left(max\left(EI_t^i + \sum_{j=1}^{N}\sum_{s=1}^{\overline{SC}} \Pi_t^{i,j\prime}\overline{AP_t^{j,s}} - \sum_{s=1}^{\overline{SC}} P_t^{i,s} + \sum_{j=1}^{N}\sum_{s=1}^{\overline{SC}} \overline{CS_t^{i,j} EV_t^j \left(\overline{AP_t^{j,s}}\right)}, 0\right), P_t^{i,S} \right) \quad (25)$$

Network model con't

- Model solution: iterative Fictious Default Algorithm (FDA)
- Start
  - Computation of initial net due liabilities of initial group of the banks and the clearing vector, identification of insolvent banks
- For each period step (period *t*):
  - Computation of net net due liabilities of surveyed banks (taking into account solvency of other institutions). If all banks' liabilities are covered with current income/capital cushion, the algorithm is stopped;
  - In the case some insolvent institutions are identified, computation of the clearing vector and identification of all connected institutions, which lost their solvency due to lack of payments from counterparties. If the propagation of first-order defaults doesn't implies bankruptcies of the banks the algorithm is stopped at this stage. If it does. Go to the previous point
- FDA stop conditions:
  - there is a lack of defaults in the certain step
  - all *N* banks have defaulted
- The number of iteration in which particular bank was found insolvent can be interpreted as its measure of vulnerability to systemic risk
- Institutions that were found bankrupt in the first round can be perceived as fundamentally/exogenously insolvent

Data

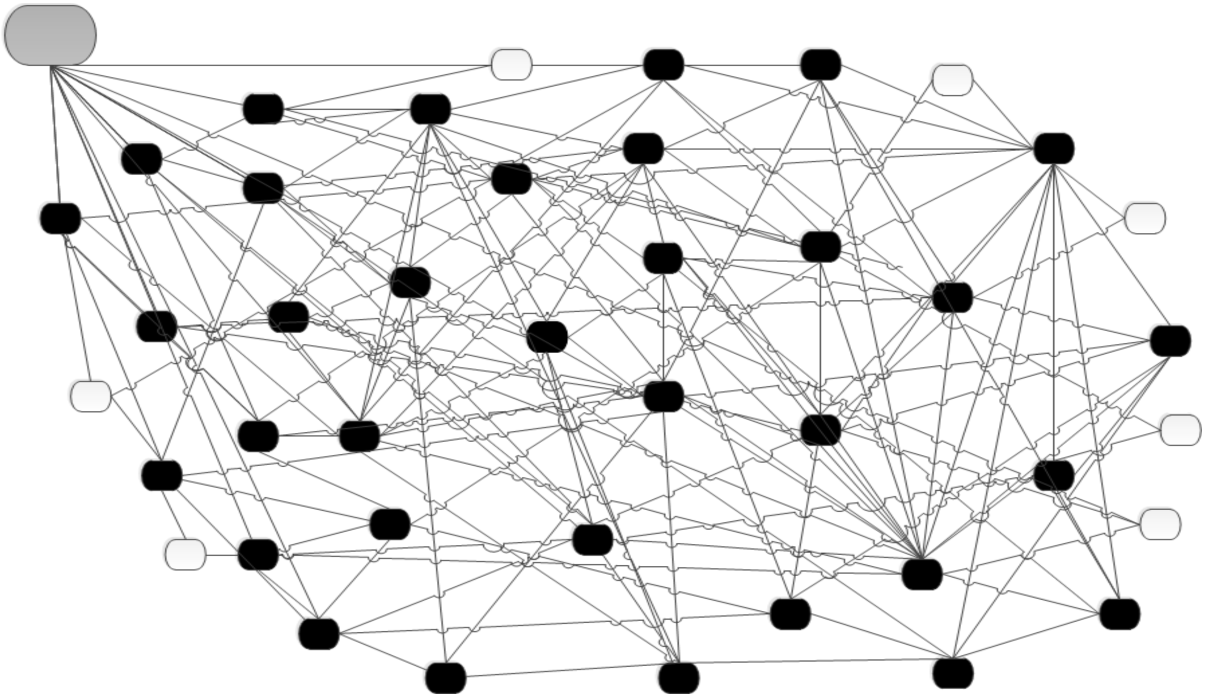
- Polish banking sector: forty biggest banks (according to total assets criterion, >= 95% of Polish banking sector total assets)
- Data from recently established prudential statistics system:
  - FINREP package (balance sheet and off-balance sheet data)
  - COREP package (capital requirements and capital structure)
  - EU Large Exposures (ELE) statistics (>= 10% of institution capital criterion)
  - Domestic Large Exposures (DLE) statistics (>= 120.000 EUR criterion)
- Historical data used for calibration: 2008-2010
- Data used for analysis: 2011-2012

Results

- The application of systemic risk model within stress-testing framework:
  - Stress test scenarios generation
  - Computation of the credit, market and liquidity risk reactions to generated shocks
  - The Fictious Default Algorithm employed to identify number of banks and their uncovered losses

Results con’t

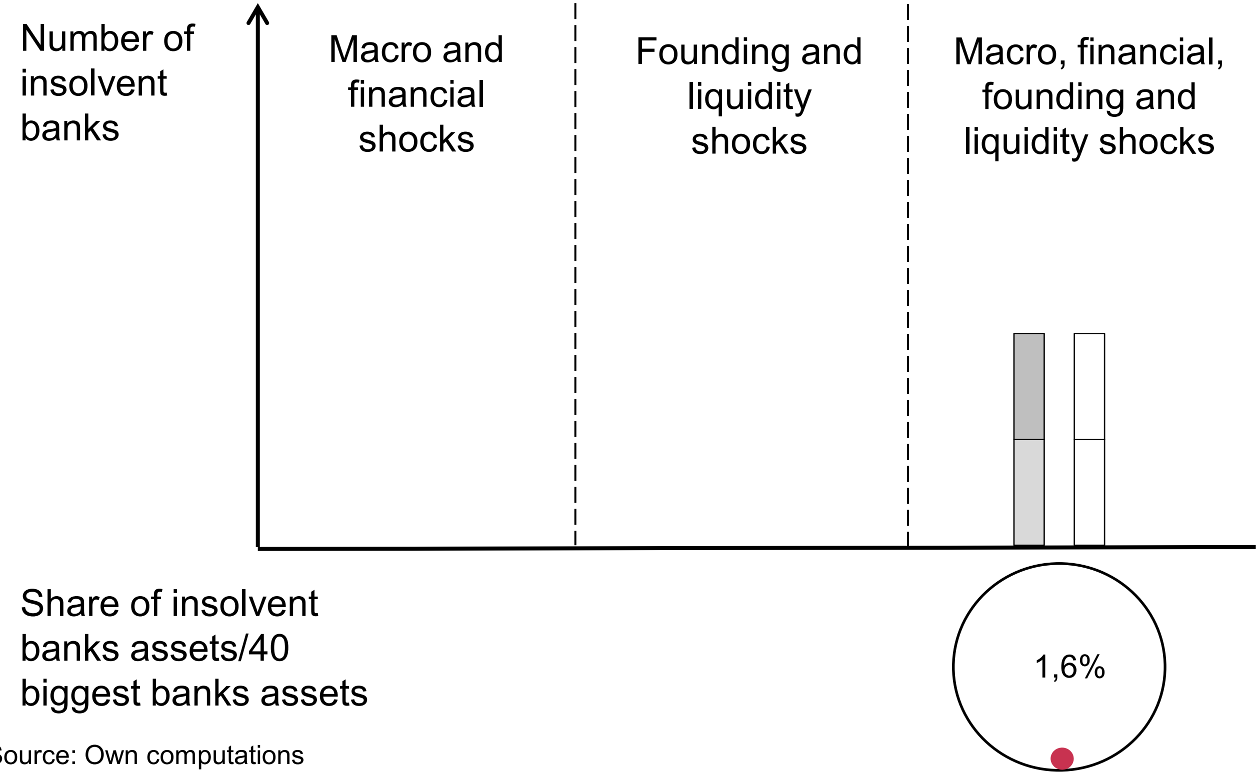
- Mutual exposures of forty biggest Polish banks:



Source: Own computations

Results con’t

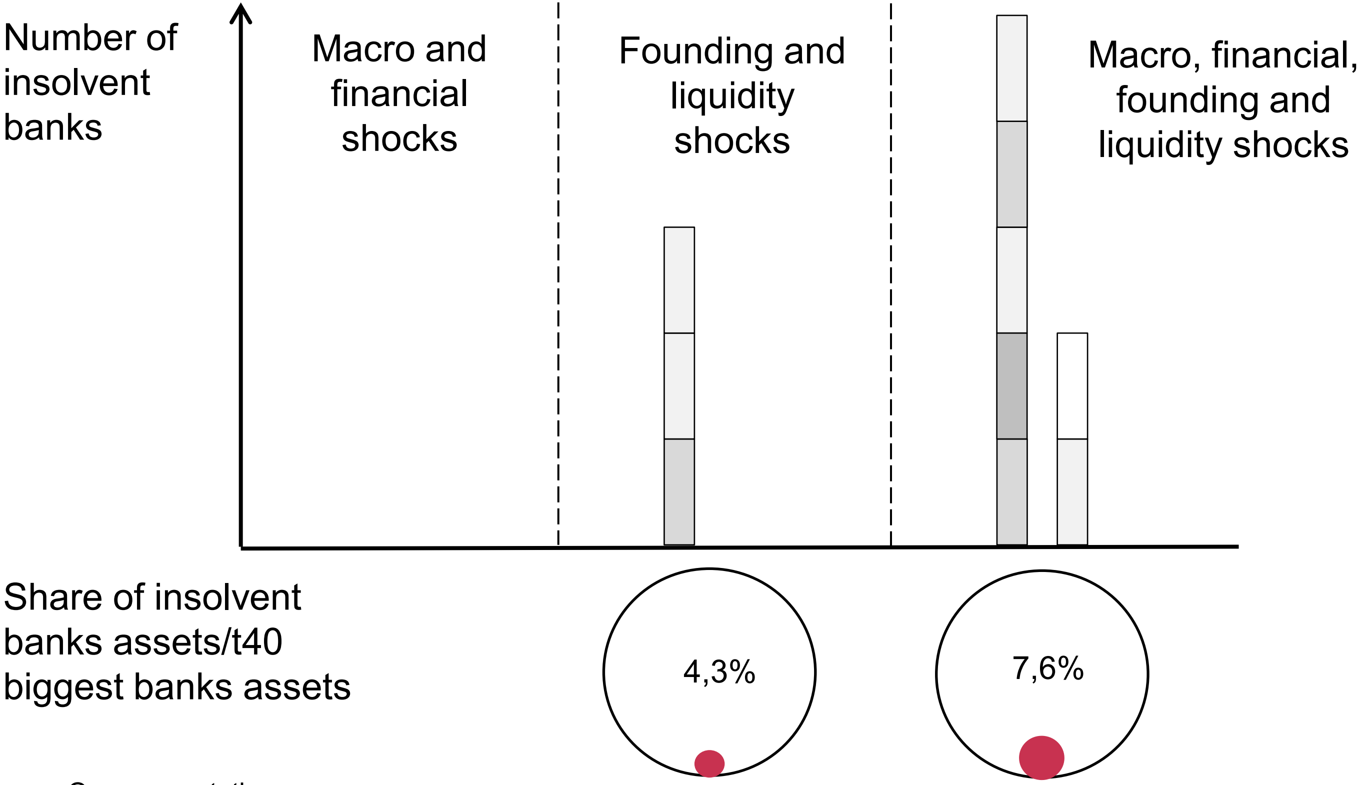
- Baseline scenario: no defaults
- Shocks scenario



Source: Own computations

Results con't

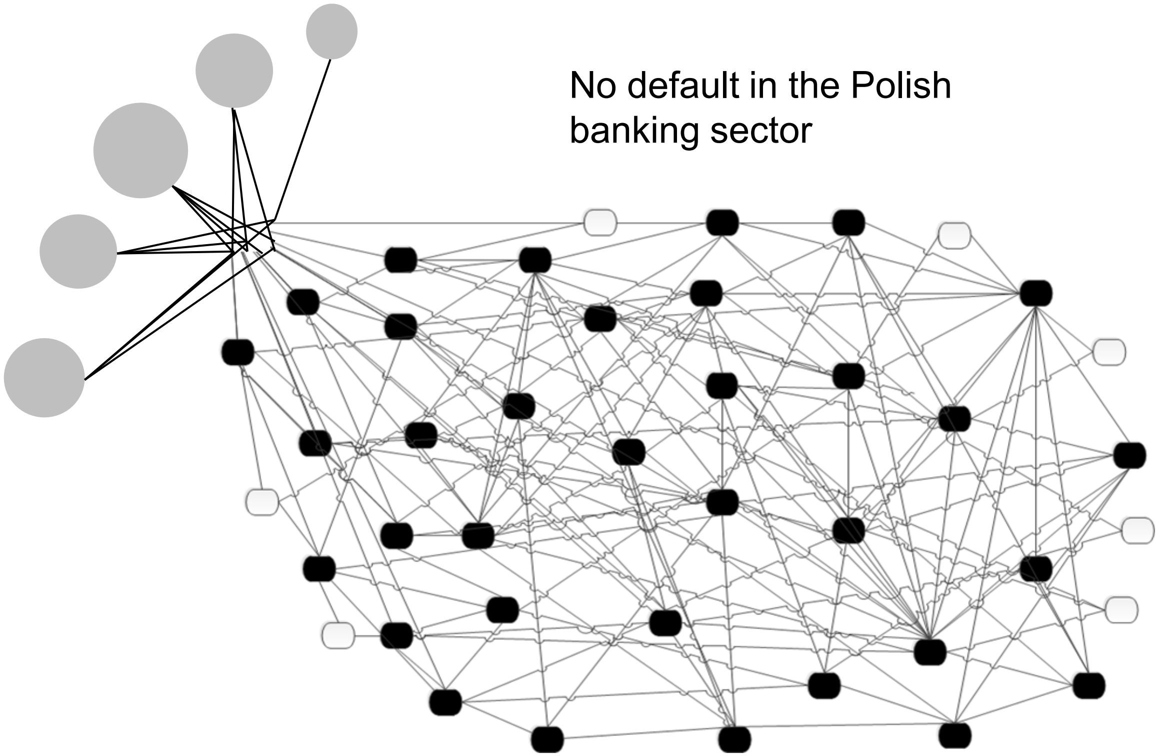
- Severe shocks scenario



Source: Own computations

Results con't

- Impact of foreign banks' insolvencies



No default in the Polish banking sector

Source: Own computations

Conclusions

- Due to traditional model of running business by vast majority of the banks operating in Poland the domestic banking sector is generally immune to endogenous and exogenous sources of systemic risk
- Relative low value of liabilities of Polish banks resulting from (secured and unsecured) interbank loans, balanced structure of assets (with extremely small share of structured instruments like ABS, MBS, etc.), adequate level of leverage of the majority of institutions and excessed liquidity of the Polish banking sector are strong pillars of the Polish banking sector stability
- Even in the case of severe macroeconomic, financial, founding and liquidity shocks' combination, only about one fifth of the 40 analysed Polish banks are tackled by systemic risk. None of these banks is systemically important one

Conclusions con’t

- The domino effect will have limited influence on the banks operating in Poland causing, depending on the shock scenario, two or three banks’ insolvencies in the second round of the systemic risk impact simulation
- The stress testing of the exogenous risk confirmed lack of statistically important influence on the local institutions of the 5 biggest foreign parent banks’ insolvencies
- However the structure of capital ownership of some domestic banks and structure of some banks credit portfolios can be source of the systemic risk for the Polish banking sector

Literature overview

- Sources of systemic risk:
  - Amplification of risks materialized on global financial markets: Gai and Kapadia (2010), Drehmann and Tarashev (2011)
  - Real economy negative shocks: Bordo, Mizrach and Schwarz (1995), Gorton (1988), Kodres and Pritsker (1999), Kyle and Xiong (2000), Lindgren, Garcia and Saal (1996)
  - Bank runs and mutual contagions: Sheldon and Maurer (1998), Chen (1999), Allen and Gale (2000), Freixaas, Parig and Rochet (2000), Wells (2002), Upper and Worms (2004), Mistrulli (2007), Castrén and Kavonius (2009), Degryse et al (2010), Espinosa-Vega and Solé (2010)
- Alternative models of systemic risk measurement:
  - CoVaR: Adrian and Brunnermeier (2010)
  - Co-Risk: Chan-Lau (2009)
  - Systemic Expected Shortfall models Acharya, Pedersen, Philippon and Richardson (2010)
- Network models of systemic risk measurement:
  - Allen and Babus (2009, Eboli (2004), Eisenberg and Noe (2001)

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