Agreggate indices for financial stability as early warning indicators for monetary measures in the Republic of Macedonia

MSc Aleksandar Petreski & MSc Elena Mucheva Mihajlovska

Skopje, April 8, 2016

Research goals

- To create reliable financial stability indices, which could be used for early detection of financial stress;
- To introduce and check new methods of creating financial stability index;
- To check whether the indices could precisely identify crisis periods in the Macedonian financial system;
- To identify the main drivers of financial stability;
- To check whether the indices of financial stability as indicators of systemic risk are triggering materialization of credit risk, as the most important risk;
- By using the SVAR model, to check interdependence between the index of financial stability and monetary policy;
- To test whether the Threshold VAR model and Markov-Switching VAR model could help in identification of periods of financial stress;
- To check whether adding financial stability index in the VAR models improves the prediction power regarding macroeconomic variables;
- To test whether reaction of the financial stability index to the change in monetary policy, depends on the state of the financial system (stability/financial stress or instability).

Outline

- Construction of indices for financial stability
- Projections of indices
- Materialization of Systemic risk
- Structural VAR (SVAR)
- Threshold VAR (TVAR)
- Markov-Switching VAR (MSVAR)
- Conclusions

Financial Stability Indices

- 8 Financial Stability Indices constructed.
- All 8 indices used common set of quarterly variables for a ten year period (2005-2015):

-Banking indicators:

1.Credit risk: Loans to households / GDP; Loans to non-financial companies / GDP

2.Liquidity risk: Loans / deposits; Deposits of non-financial entities

3.Currency risk: Foreign currency deposits / total deposits

4. Interest rate risk: Interest rate on denar long-term loans to households; interest rates on denar long-term loans to non-financial entities; Interest rate spread between newly approved denar deposits and loans

-Non-banking indicators:

1.Macedonian Property Index

2.Macedonian Stock Exchange index (MBI 10)

3.Current account balance / GDP

Financial Stability Indices

- 8 methods for construction of indices

The idea is to get a multi-faceted perspective on the state of the financial system and reduce the risk of misidentification of financial stability.

I. Portfolio method:

data are aggregated by the principles from portfolio theory

$$\mathbf{Index=(w*x_t)*C_t*(x_t*\ w)'}$$

$W=(w_1, w_2, w_3 \ldots\ w_{11})$ is a vector of constant equal weights

X_t is a vector of variables

C_t is matrix of dynamic cross correlation between the variables (EWMA model)

Gives more weight to periods in which financial stress occurs simultaneously in multiple variables. It is expected that systemic risk is greater when the correlation between variables increases.

Financial Stability Indices

Next 4 indexes are modified versions of portfolio method of creating indices, used in Hollo at al.(2012). Similar to the portfolio method, they dynamically model cross-correlation structure, but instead of equal weights, we use 4 different methods for determining weights.

II. Modified portfolio method with FEVD

All variables are modeled with the VAR model and estimated FEVD coefficients are extracted from the model. From the extracted FEVD coefficients of influence of one variable on another, the mean is calculated for every variable, which represents its weight.

III. Modified portfolio method with dynamic variances

Uses weights obtained in dynamic modeling of variance. Variance model is calculated with dynamic EWMA model, with parameter $\lambda=0.94$.

$$\sigma_n^2 = \lambda \sigma_{n-1}^2 + (1 - \lambda) u_{n-1}^2$$

Variables with higher value of variance, have a higher weight.

Financial Stability Indices

IV. Modified portfolio method with signals

Variables gain appropriate weight according to their predictive power of modeling GDP. The greater the predictive power of a variable on the direction of GDP movement, the higher the weight factor.

GDP is used, since later the study tests whether adding financial stability index in the VAR models improves the prediction power in GDP modeling.

V. Modified portfolio method with simulations

Weight factors are obtained by 10,000 simulations, which are used to calculate the index. As optimum weight factor is considered the one that will display the smallest root mean squared error when regressing the index on GDP.

Financial Stability Indices

VI. Principal Components method

Through eigenvalue decomposition of the matrix of variances of the variables, major components are extracted that explain most of the variability of the group of variables. Reduction of variables is done by selection of those main components that explain at least 90% of the variance of the system (in this case 7 components out of 11)

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11
Standard deviation	16.100	14.659	12.558	11.677	100.945	0.86699	0.80268	0.65908	0.51179	0.39132	0.2321
Proportion of Variance	0.2356	0.1954	0.1434	0.1240	0.09264	0.06833	0.05857	0.03949	0.02381	0.01392	0.0049
Cumulative Proportion	0.2356	0.4310	0.5744	0.6983	0.79097	0.85931	0.91788	0.95737	0.98118	0.99510	10.000

VII. Value at Risk method

Assuming a normal distribution of the variables, a weight factor for each variable is obtained using opposite normal function, wherein the inputs are: probability of 95%, dynamic average and dynamic standard deviation.

Financial Stability Indices

VII. Average Financial Stability Index

-arithmetical average of results from previously calculated 7 Indices.

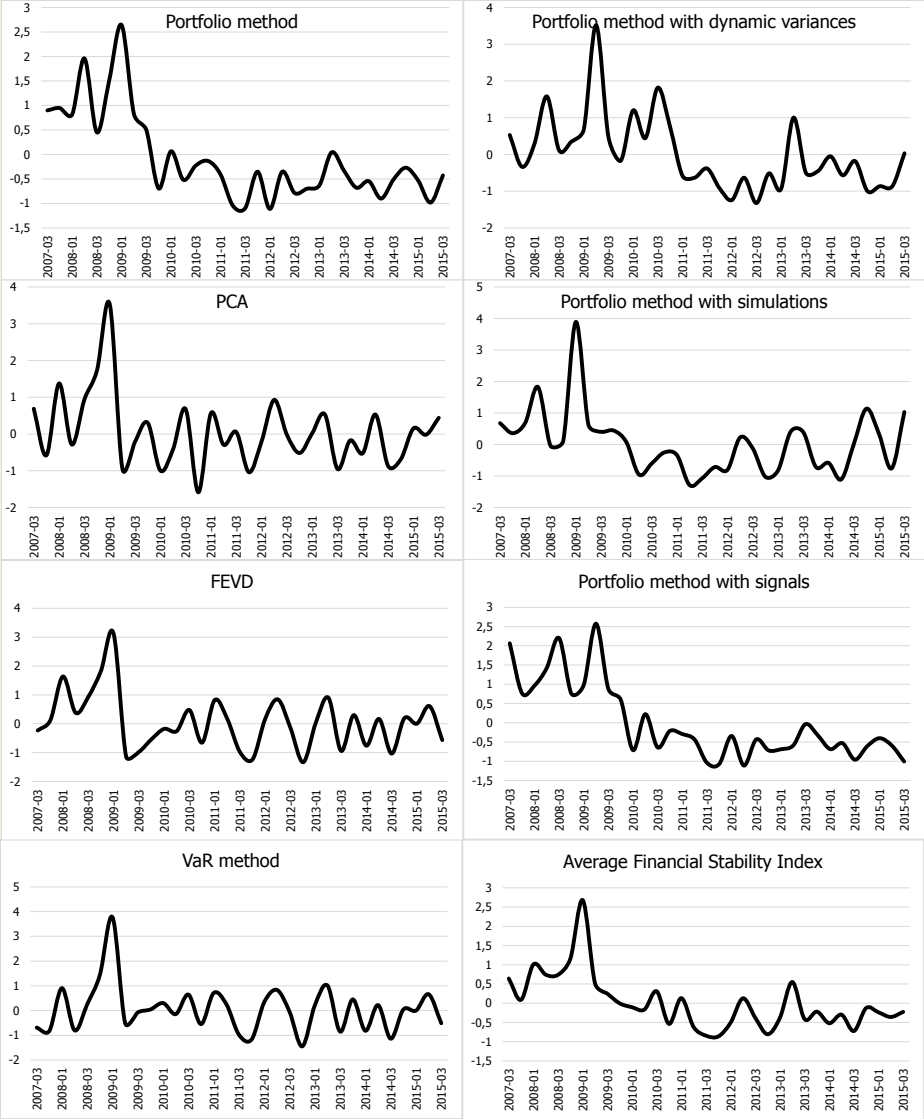
-the idea of combining methods is coming from models for predicting GDP. The study by Stock and Watson (2004) used a combination of forecasts as more stable than the forecast of individual methods. The same idea is applied to the theory of indices,

-proved to be more reliable than using individual indices for identification of the state of the financial system,

-high degree of risk diversification of mistakes from different research methods,

-hits crisis point and has the lowest standard deviation.

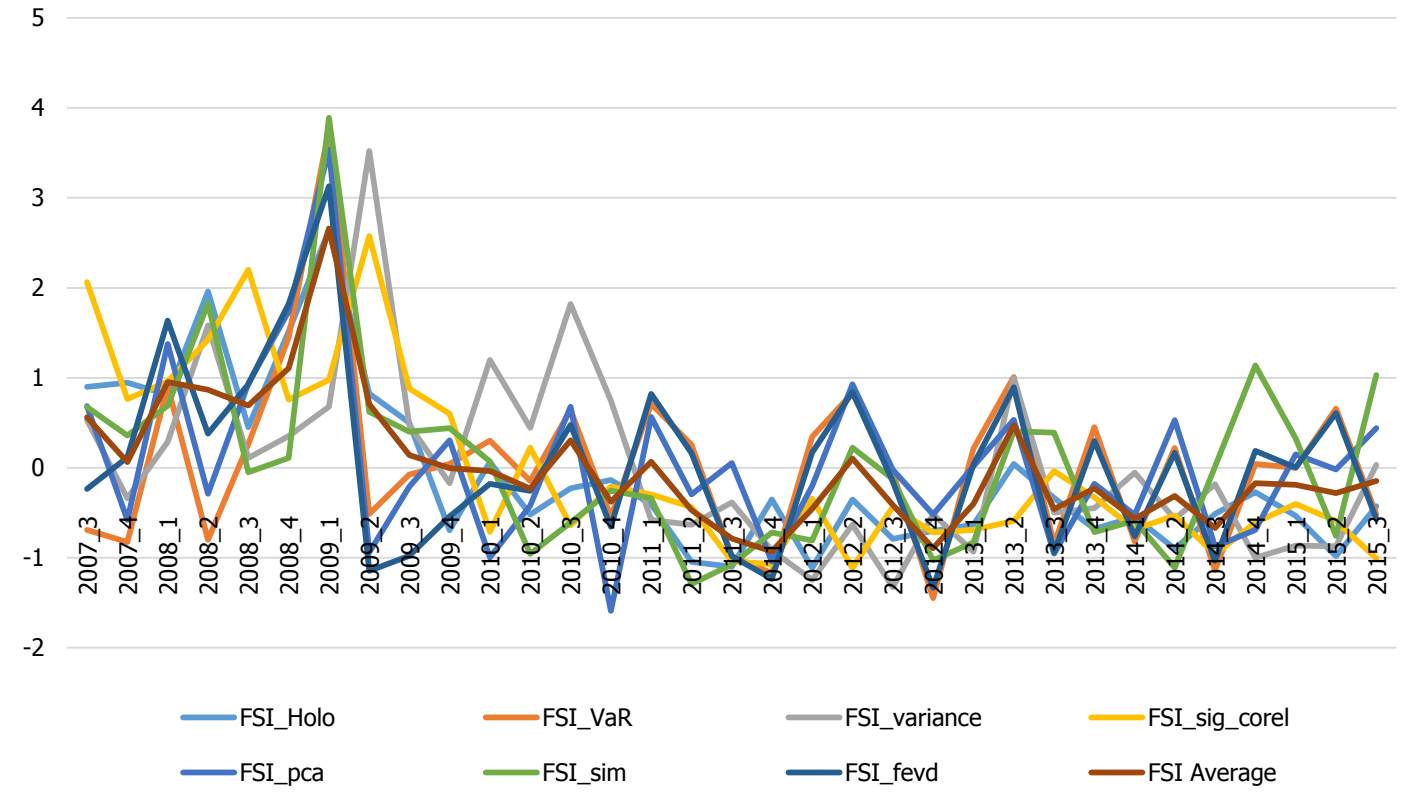
Financial Stability Indices



-their upward movement means stress (instability)
-their decrease indicates a state of stability

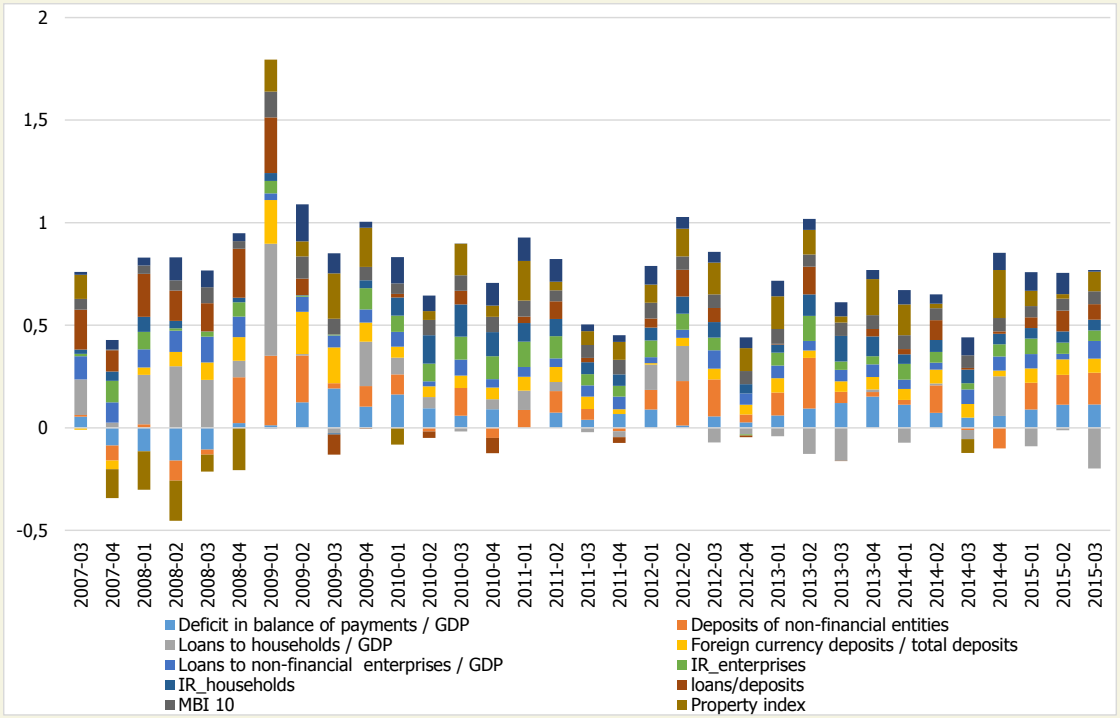
Financial Stability Indices

- 6 out of 8 financial stability indices have identified the same point of crisis. Among them is the average financial stability index, which has the smallest standard deviation.



Contributions to Financial Stability Indices

- Credit and deposit activity of banks are the main drivers of the indices. This is logical given the fact that the Macedonian financial system is bank based. During the global financial crisis, the stock index and the property index contributed as well.

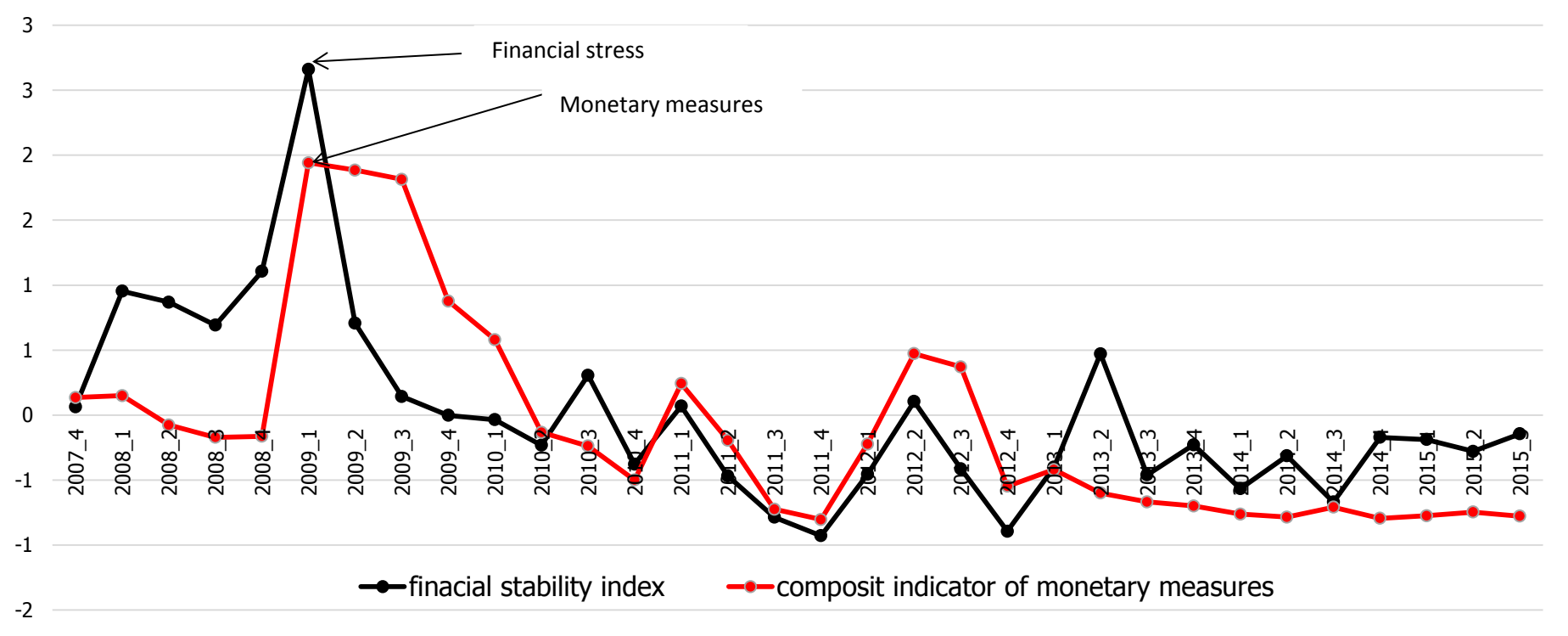


Composite indicator for monetary measures

- Assembled with monetary policy instruments: the amount of central bank bills, their interest rate and reserve requirement ratio.
- Here, the idea is to create a tool which will avoid static data for monetary policy instruments and possible problems in further empirical calculations and analysis.
- The same methods used as for Financial Stability Indices.
- In further analyses only average Composite indicator for monetary measures is used.

Financial stability index and composite indicator of monetary measures

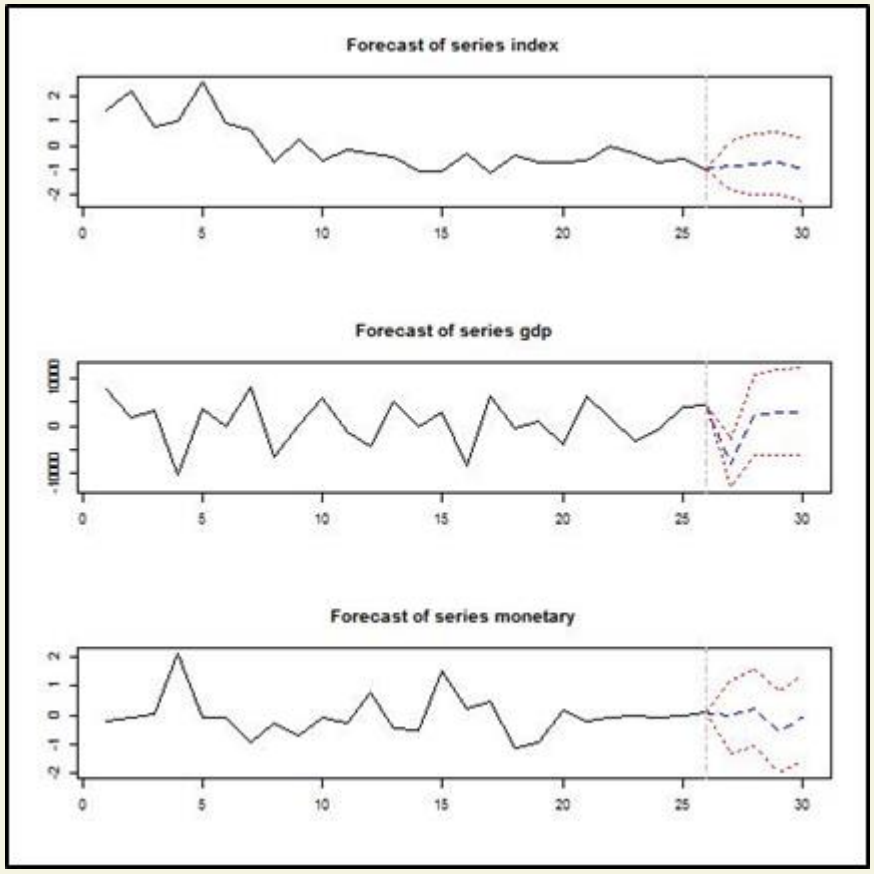
- Movement of the Composite indicator for monetary measures in upward direction means restrictive changes in monetary policy.



Projection / Early recognition of the financial stress

- Financial Stability index should be used to recognize a financial stress since its inception. Therefore indices are short term projected (4 quarters).
- The power of prediction of indices is measured with the calculated root mean squared error on the differences between projected and realized observations.
- Average index and the modified portfolio method of signals have the lowest RMSE - highest power for early recognition of financial stress.
- Principal component method had the best fitting in the sample, but the worst results in prediction out of the sample.

Projection / Early recognition of the financial stress



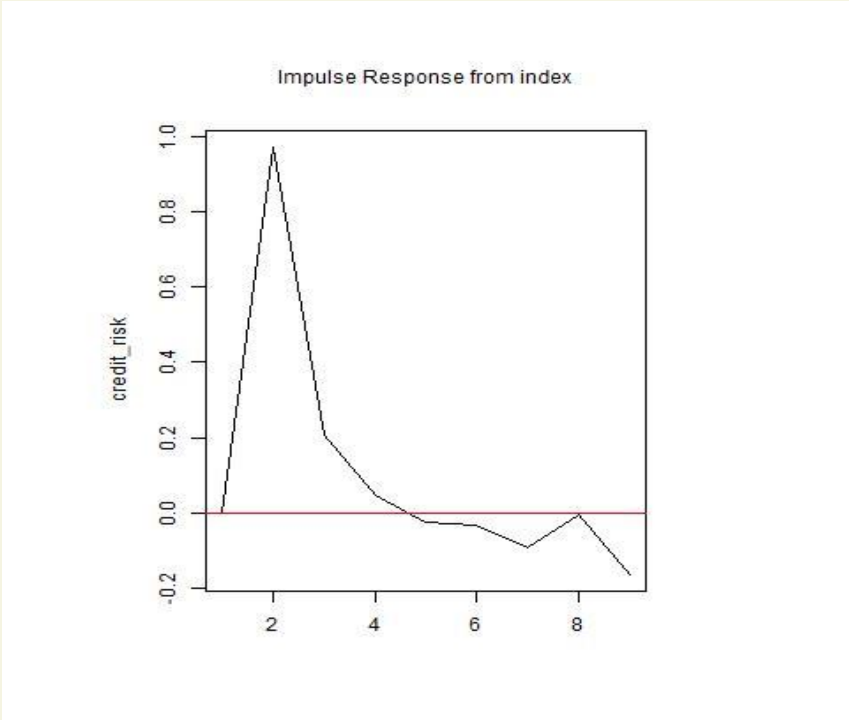
Materialization of Systemic Risk

- Is systemic risk triggering materialization of the credit risk?
- The focus is on the materialization of credit risk, as the largest risk to which Macedonian banks are exposed.
- Indicators used for credit risk:

1. The absolute level of impairment;
2. Average level of risk (impairment / credit exposure);
3. Non-performing loans / total loans;
4. The ratio between the number of borrowers who transferred to better risk category and those that deteriorated;
5. The ratio between the number of borrowers who have transferred to a worse risk category and the total number of borrowers on a given date;
6. Quarterly change in the share of borrowers in risk category "A" and "B" in the total number of borrowers on a given date.

Materialization of Systemic Risk

- 546 estimations with VAR models: 8 financial stability indexes, 6 credit risk indicators, 3 monetary variables and 4 deterministic factors.
- At each estimation, VAR and restricted VAR are calculated. Also a co-integration test is done. If there is co-integration among the factors, Vector Error Correction model (VEC) was performed.
- Impulse response functions shows that the reaction of the credit risk to the shock to Financial Stability Index is usually initiated after 2 quarters.



SVAR and Indices

- Through the use of structural vector auto-regression models (SVAR), this study sought to investigate the links:
  - index -> monetary measures
  - monetary measures -> index.
- Specifically, the study tries to answer:
  - whether central bank perceive the crisis in a timely manner,
  - whether it take appropriate measures and
  - do undertaken measures affect the financial stress.

SVAR and Indices

- In this paper, the structural vector autoregressive (SVAR) model is used to analyze short-run and contemporaneous relationships between financial stability index and macroeconomic variables.
- The underlying assumption that innovations in the different equations are uncorrelated (that is diagonal) is in general not compatible with the observed data and with the theoretical background. This requires imposing restrictions on the correlation structure of the VAR residuals.
- To explain the intuition behind the orthogonality restriction in SVAR models, Bernanke writes:

  "…think of the structural innovations as 'primitive' exogenous forces, not directly observed by the econometrician, which buffet the system and cause oscillations. Because these shocks are primitive, i.e., they do not have common causes, it is natural to treat them as approximately uncorrelated."

SVAR and Indices

- SVAR restrictions

1) restriction
index -> all variables
monetary policy -> index

	indeks	gdp	monetary p.
indeks	1	0	NA
gdp	NA	1	0
monetary p.	NA	0	1

2) restriction
index -> all variables
monetary policy -> gdp

	indeks	gdp	monetary p.
indeks	1	0	0
gdp	NA	1	NA
monetary p.	NA	0	1

3) restriction
index -> all variables
gdp -> index
monetary policy is not influencing anyone

	indeks	gdp	monetary p.
indeks	1	0	0
gdp	NA	1	0
monetary p.	NA	NA	1

4) restriction
index -> monetary policy
gdp -> index, monetary policy
monetary policy is not influencing anyone

	indeks	gdp	monetary p.
indeks	1	NA	0
gdp	0	1	0
monetary p.	NA	NA	1

5) restriction
index -> monetary policy
gdp -> monetary policy
monetary policy -> index

	indeks	gdp	monetary p.
indeks	1	0	NA
gdp	0	1	0
monetary p.	NA	NA	1

6) restriction
index -> monetary policy
gdp -> monetary policy
monetary policy -> gdp

	indeks	gdp	monetary p.
indeks	1	0	0
gdp	0	1	NA
monetary p.	NA	NA	1

7) restriction
index is not influencing anyone
gdp -> index
monetary policy -> all variables

	indeks	gdp	monetary p.
indeks	1	NA	NA
gdp	0	1	NA
monetary p.	0	0	1

8) restriction
index -> gdp
gdp is not influencing anyone
monetary policy -> all variables

	indeks	gdp	monetary p.
indeks	1	0	NA
gdp	NA	1	NA
monetary p.	0	0	1

9) restriction
index -> monetary policy
gdp is not influencing anyone
monetary policy -> all variables

	indeks	gdp	monetary p.
indeks	1	0	NA
gdp	0	1	NA
monetary p.	NA	0	1

10) restriction
index is not influencing anyone
gdp -> monetary policy
monetary policy -> all variables

	indeks	gdp	monetary p.
indeks	1	0	NA
gdp	0	1	NA
monetary p.	0	NA	1

"0" - established restriction
"NA" - no restriction

SVAR and Indices

- Which combination of SVAR restrictions is best? How to detect the best SVAR combination?
- We use dummy-variable regression of categorical variables on the log-likelihood, to see the impact of categorical variables (type of monetary variables, type of index, a restriction, a deterministic factors in the model).

  svar_llikelihood ~ monetary_variable_type + index_type + det_type + restrict_type

  SVAR likelihood is estimated with

$$\ln L_c(A,B) = -\frac{KT}{2}\ln(2\pi) + \frac{T}{2}\ln|A|^2 - \frac{T}{2}\ln|B|^2 - \frac{T}{2}tr(A^\top B^{-1\top} B^{-1} A\bar{\Sigma}_u),$$

- The largest contribution to the increase in log-likelihood have the restriction No.1 (which is encompassed in the intercept). Within the restriction No.1, it is assumed that in the short term:
  - the index affects the monetary policy, and monetary measures have an impact on the index.
  - the index affects the GDP, while GDP does not affect index;
  - monetary measures does not affect GDP and GDP does not impact monetary policy (due to time delay);

SVAR and Indices

- Which pair of SVAR restrictions is best? How to detect the best SVAR restrictions on pairs?
- Again, we assess the impact of any restriction on the pair variables on the log-likelihood, through dummy-variable regression of restricted pairs (1 – restriction on pair of variables, 0 - no restriction on the appropriate pair)

  svar_llike ~ rbm + index + det_type + svar_cig + svar_cim + svar_cgi + svar_cgm + svar_cmg

  where

  svar_cig = 1/0 restriction on index -> gdp
  svar_cim = 1/0 restriction on index -> monetary policy
  svar_cgi = 1/0 restriction on gdp -> index
  svar_cgm = 1/0 restriction on gdp -> monetary policy
  svar_cmg = 1/0 restriction on monetary policy -> gdp
  svar_cmi = 1/0 restriction on monetary policy -> index

- Among restrictions, the strongest contribution to reduction of log-likelihood has the restriction on pairs: the index -> variable monetary and monetary variable -> index.
- Pairs of variables that reduce the log-likelihood are least likely candidates to be limited and should not be restricted, but calculated (svar_cim and svar_cmi, which is encompassed in the intercept).

SVAR and Indices

- We checked the t-statistics for the relationship between the index and monetary variable and sign of the t-statistic in SVAR model.

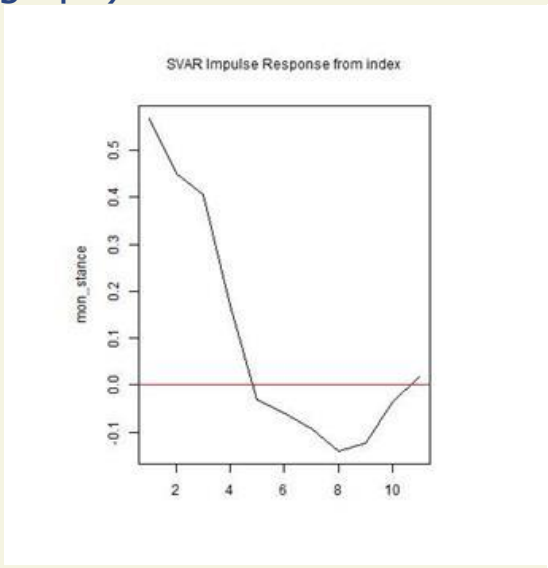
	index -> monetary measures	monetary measures -> index
	">"	"<"
<=-2	21%	34%
> -2 & < 2	1%	12%
>= 2	51%	38%
uncomputed	27%	16%

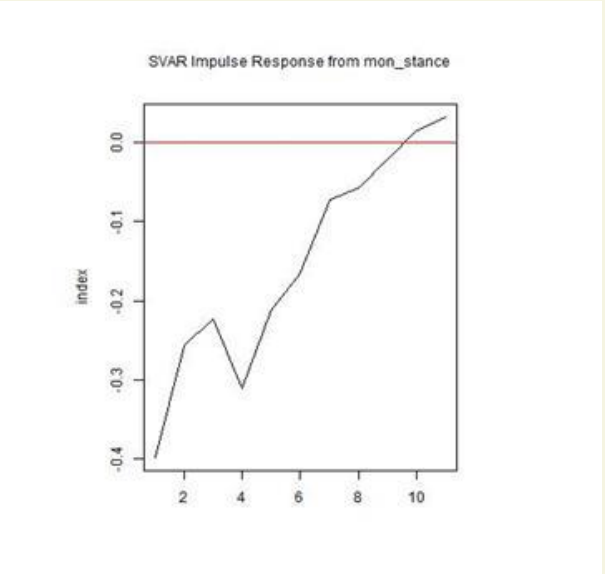
(% in the table are distribution of t-statistics)

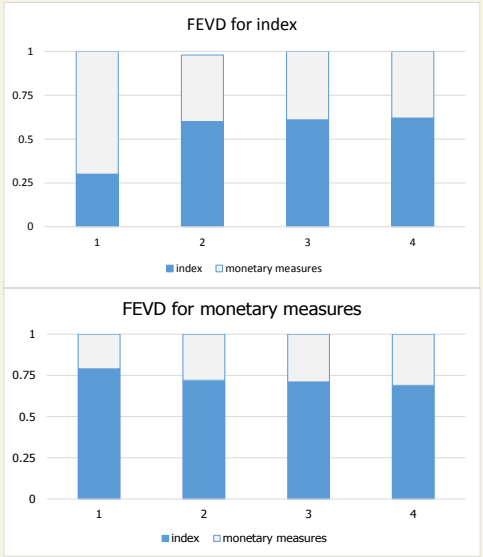
- In relation **index = (+/-) monetary variable** "+" sign dominates for the t-statistic, which indicates that when the index changes, the monetary policy instruments operate in the same direction.
- When the index is growing, monetary policy becomes more cautious and restrictive and conversely, when the index is decreasing, monetary policy becomes more relaxed.
- The sign of the t-statistic in the relationship **monetary variable = (+/-) index** in certain situations is positive, and in some situations the sign of t-statistic is negative.
- Different signs of reaction to the index of monetary measures, means that in different situations the index reacts differently to the monetary policy measures. The reaction of the index to monetary measures depends on the state of the financial system (stressful situation, normal).

SVAR and Indices

- The analysis of forward error variance decomposition is confirming the interaction between the index of financial stability and the monetary variable. Shock in the index results in increase of the restrictiveness of the monetary measures (left graph). Shock in the monetary measures result in the decrease in the index (middle graph). The impact of the index of financial stability on the monetary measures is stronger than vice versa (right graph).







- In conclusion, the results show that the Central bank anticipates the crisis in a timely manner and takes measures. Undertaken measures have an impact on reducing the financial stress, mostly because of the strong influence of banking indicators in the composition of the index for financial stability.

TVAR and Indices

- The results of the SVAR model showed that the reaction of the index of financial stability of monetary policy depends on the state of the financial system (stability / financial stress). For these reasons, a VAR model with thresholds (TVAR) is used, by means of which the reaction of the index to monetary measures is isolated in the state of stability and the state of financial stress.

- Due to possible problems of nonlinearity in classical VAR models, the study is investigating whether the use of the TVAR model with an index of financial stability, as a proxy for the health of the financial system, helps process macroeconomic modeling.

- The study uses a two-regime model (regime of stability/financial stress), using quarterly data changes for Macedonia in the period 2005-2015.

TVAR and Indices

- Performed 192 assessments and forecasts for each of the following models:
  - 1) VAR – where variables are macroeconomic variables (GDP, inflation) and monetary variable,
  - 2) VAR – where variables are macroeconomic variables (GDP, inflation), monetary variable and index on financial stability,
  - 3) TVAR- where endogenous variables are macroeconomic variables (GDP, inflation), monetary variable and index of financial stability, which is threshold variable as well,
  - 4) TVAR- where endogenous variables are macroeconomic variables (GDP, inflation) and monetary variable, while exogenous variable is the index on financial stability, which is threshold variable as well.
- Before TVAR estimates are done, we test linearity/specification of the models. Results confirm presence of nonlinear cases. In the endogenous model only 5% show nonlinearity with 2 thresholds, while in the exogenous model 6% of non-linear cases show nonlinearity with 2 thresholds.
- Therefore the study uses the TVAR model with 1 threshold (2 regimes).

TVAR and Indices

- RMSE of prediction on GDP by 4 models

	var (rmse)	var + index (rmse)	TVAR1 (rmse)	TVAR2 (rmse)
average	1.7929%	2.1828%	1.6302%	1.7173%
3 variables	1.6517%	1.9234%	1.5092%	1.2321%
4 variables (+ inflation)	1.9342%	2.4421%	1.7513%	2.2025%
r	2.0450%	2.3333%	2.0081%	2.0706%
b	1.7675%	2.2384%	1.6106%	1.6019%
m	1.5663%	1.9766%	1.2719%	1.4794%

"r" - interest rate on central bank bills
"b" - amount of central bank bills
"m" - composit indicator of monetary measures

- Among types of models and used monetary variable, the lowest average RMSE has the endogenous TVAR1 model with composite indicator of monetary measures, as a monetary variable (1.2719%).
- "Dummy-variable" regression on RMSE shows that among endogenous TVAR1 models, models with index based on VaR and index based on variance have the smallest RMSE, while among exogenous TVAR2 models, models with average index have the smallest RMSE.

TVAR and Indices

- Best models for GDP prediction, after linearity check

	% of cases of best model	% cases of non-linear residulas	% of cases of best model (with linear residuals)
rmse VAR	10%	40%	7%
rmse VAR+index	33%	76%	42%
rmse TVAR1	16%	45%	12%
rmse TVAR2	41%	56%	39%

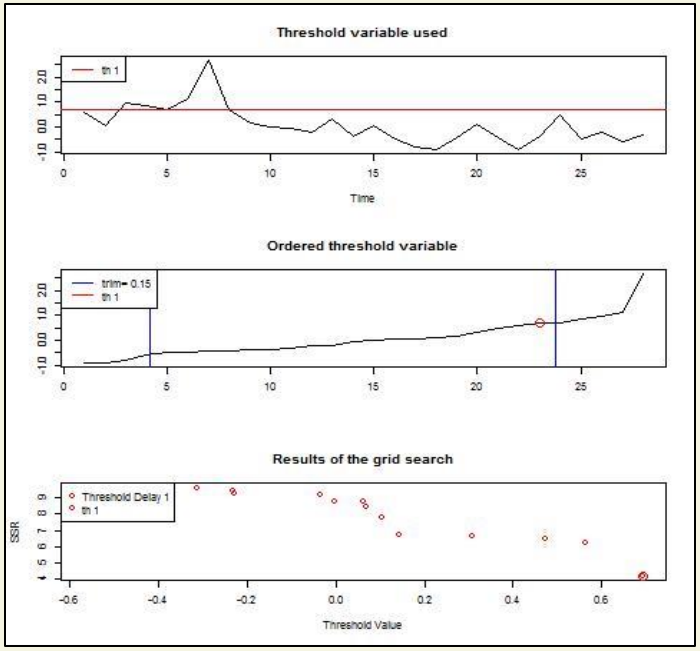
- On average, the exogenous TVAR2 model and the VAR+index model have a higher percentage of cases with the lowest RMSE have (41% and 33%, respectively).

- If we consider only cases which pass the tests of linearity, non-autocorrelation and homoscedasticity, a higher percentage of cases with the lowest RMSE belong to the exogenous TVAR2 model and the VAR+index model (39% and 42%, respectively).

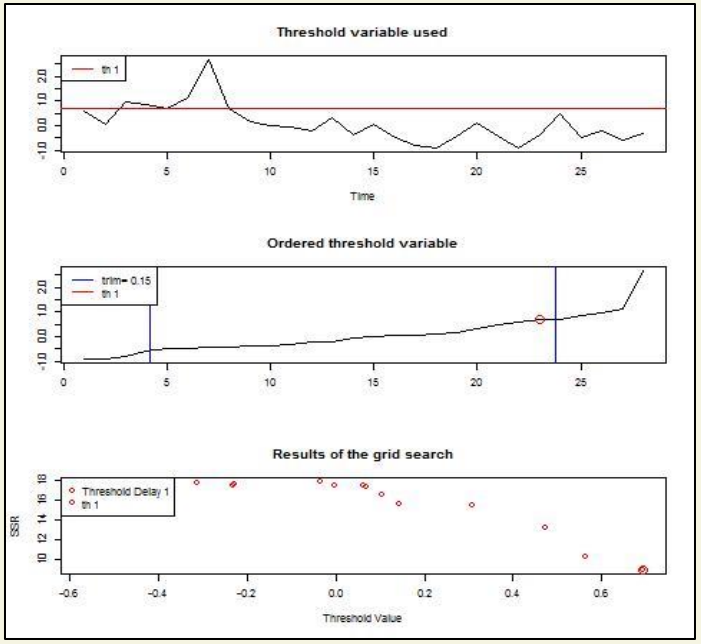
TVAR and Indices

- Identifying financial stress using the thresholds from TVAR models

1) TVAR1 model, average index



2) TVAR2 model, average index



By using estimated “thresholds”, we can distinguish whether the financial system is in stress or not. Charts of the best models identify the financial stress of 2008-2009.

TVAR and Indices

- Coefficients from TVAR model – average index

average index		constant	index	monetary measures
monetary measures	regime stability	0.29	-0.14	0.53
	regime "stress"	2.27	0.75	2.74
index	regime stability	-0.43	0.37	0.29
	regime "stress"	2.44	-2.32	-4.84

- Monetary measures equation

The constant for monetary measures in the regime “financial stress” is higher (0.29) than in the regime “stability”(2.27), which confirms that monetary policy is becoming restrictive (higher interest rates, higher amount of central bank bills).

In the regime “stability” the coefficient for reaction to changes in the index is negative and not very significant (-0.14), while in the regime “financial stress” the coefficient is positive and stronger (0.75).

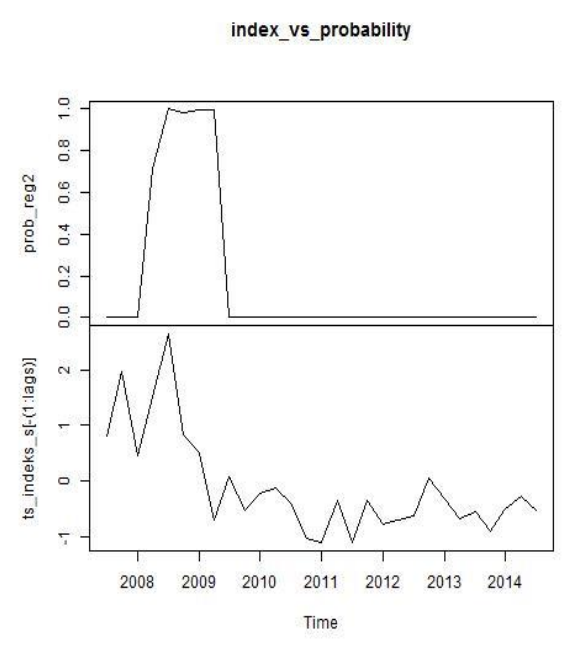
- Index equation

The constant for index in the regime “financial stress” is higher (2.44) than in the regime “stability” (-0.43), as we expected. The coefficient for monetary measures in the regime “stability” is positive and not very significant (0.29), while in the regime “financial stress” the coefficient is negative and much stronger (-4.84).

Markov Switching VAR and Indices

- Unlike threshold TVAR models, which are driven by economic variables visible in the form of thresholds, Markov Switching VAR models (MSVAR) are driven by invisible stochastic variables (states, regimes). 2 hidden states are assumed as possible and that they affect all: the conditional mean, the conditional variance and the conditional correlation structure that characterizes multivariable process. This regime variable St is hidden and unobservable, so at best its prediction can be performed in the form of probability.
- The study used a two-regime model MSVAR (regime stability, regime financial stress), using quarterly data for Macedonia in the period 2005-2015, where the variables are GDP, monetary variable and an index of financial stability.
- In the study we try to find whether the use of index on financial stability as the variable in the MSVAR model, helps the process of macroeconomic modeling. Therefore, we compared GDP prediction performance of MSVAR model to prediction performance of ordinary linear VAR model, which includes the same variables.
- Overall, the MSVAR model is showing higher RMSE compared to an ordinary VAR model, except when MSVAR is using index with portfolio method/variance method, and monetary index/interest rate on central bank bills as a monetary variables, respectively.
- We assume that the reason for the weaker predictive power of the MSVAR model is that these models have too much parameters relative to short series of data (33 quarterly points).

Markov Switching VAR and Indices

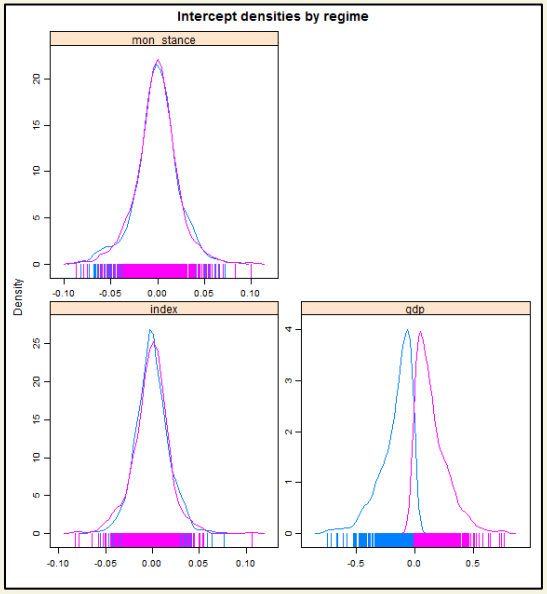


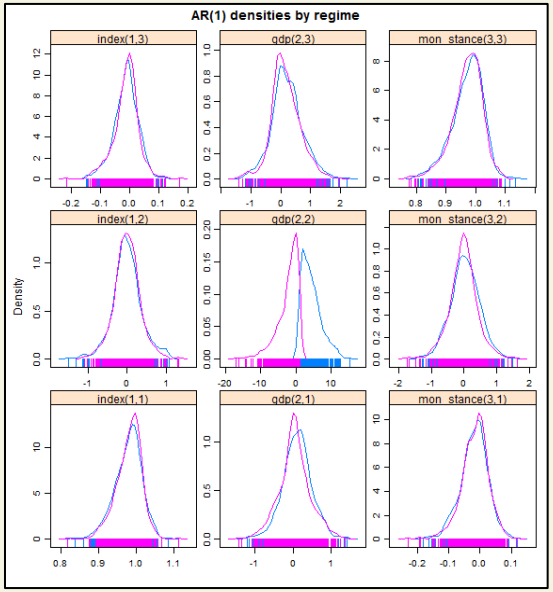
MSVAR results:

- MSVAR models help in visual identification of low and high regimes (states) of stability, which is a hidden variable. By fitting MSVAR models in the sample, we can get as a parameter the probability of financial system being in some state of stability (low/high).

- Almost all models indicate that the probability is high (>0.9) that the Macedonian financial system was in distress, during the recent global financial crisis in 2008-2009.

Markov Switching VAR and Indices





MSVAR results:

- We analyze the parameters estimated from the MSVAR model, to check if there is a significant difference in their densities. Dependent on the state of the financial system (stability/financial stress), only coefficients in the GDP equation (constant and coefficient of relationship GDP - GDP) showed a significant difference among the states.
- However, this results should be taken with caution due to to-short series used in MSVAR model.

Conclusions (1):

- This study introduced new kind of financial stability index, "average index" as a contribution to the existing methodology for creating financial stability indices.
- In the research, we tested the performance of the average index and the results show that the average index is one of the indices that show the smallest error in prediction, which means it can be used for early detection of financial crises.
- Furthermore, this study has contributed with several new methods of creating indices, which are a modified version of the portfolio method of creating indices.
- Using the average index and other indices, the effect of global financial crisis of 2008-2009 on Macedonian financial system was accurately identified.
- Specifically, this study shows that credit and deposit activity of banks are the main drivers of financial stability. Also, the stock index and the property index moderately influence stability of the financial system.
- The survey confirmed that the indices of financial stability as indicators of systemic risk are triggering materialization of the credit risk and usually effects are realized after two quarters.

Conclusions (2):

- Tested SVAR model showed that there is a strong instant relation between the index of financial stability and monetary policy and vice versa. Also, the SVAR model showed that the impact of the financial stability index on monetary policy is proportional and stronger than the impact of monetary policy on the financial stability index, which in some situations is proportional and in some situations is inversely proportional.

- Using parameters from the estimated TVAR (threshold) and Markov Switching VAR model (probability of financial system being in some state of stability), the study clearly identifies crisis periods in 2008-2009, when global financial crises affected the Macedonian financial system.

- The research showed that adding financial stability index in the VAR models improves the prediction power of macroeconomic modeling. Except for the MSVAR model, other models: TVAR and linear VAR models which include financial stability index, have greater predictive power than linear VAR models without the financial stability index.

- TVAR results show that in normal conditions, increases in the index are not perceived as a sign for crisis, but rather a noise and the central bank can afford a relaxed policy. On the contrary, if the index has increased dramatically, the central bank considers that crisis has begun and it takes restrictive measures against it. Also, in normal conditions, decrease in monetary measures is decreasing the index. It might be that market participants are perceiving the central bank signal of relaxed policy as a confirmation that the financial system is stable. Conversely, in crisis, the reaction of the index switches and the index decreases, if monetary measures becomes restrictive. It might be that market participants, aware of the crisis, are perceiving the restrictive monetary measures as a preparedness of the central bank to tackle the situation with all means.

THANK YOU!

MSc Aleksandar Petreski & MSc Elena Mucheva Mihajlovska
PetreskiA@nbrm.mk MucevaE@nbrm.mk

Financial Stability and Banking Regulation Department
National Bank of the Republic of Macedonia