Academy of Economic Studies Bucharest
Doctoral School of Finance and Banking

A macroeconomic credit risk model for stress testing the Romanian corporate credit portfolio

Supervisor
Professor PhD. Moisă Altăr

MSc. Student
Tanase Isabela

July 2013

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Motivation and Objectives

Motivation

- Credit risk outweighs the other risks as banks' loans to companies and households constitute about 60% of the sector's assets, loans to the corporate sector is having the greatest share of 30%
- The increased attention of financial authorities in maintaining financial stability as a part of the macro prudential framework
- The cyclical nature of bank credit, NPL, and loan loss provisions.

Objectives

- This study aims to capture credit risk in dependence with macroeconomic variables by modeling the relationship between corporate default rates and macroeconomic factors
- Default rates will be simulated over time by generating macroeconomic shocks to the system
- Based on the simulation of default rates, estimates of expected and unexpected loss will be determined in case of a specified corporate loan portfolio
- The model will used for performing macroeconomic stress tests in order to determine the resilience of the Romanian banking sector against the proposed crisis scenarios

Implementation of objectives

- A set of econometric models will be developed in order to determine which are the macroeconomic variables that can signal the modifications in default rates
- Evolution of macroeconomic variables will be forecast under a horizon of 1year
- Based on the estimates of macroeconomic fundamentals, the evolution of default rates per sector under a horizon of 1year
- Correlation between individual macroeconomic variables are modeled as to account for interdependencies
- Construct an arbitrarily corporate loan portfolio, considering the percentage distribution of corporate loans by industry and determine the expected and unexpected loss by using the estimated paths of default rates
- Perform stress testing as to determine the impact of a shock of macroeconomic variables on default estimates by using extreme worst case historical shocks for all explanatory macroeconomic variables of default rates

Literature review

Most of the research in the area of macroeconomic credit risk modeling is based on the approach of **Merton(1974)** and **Wilson(1997a,b)** . This approaches were applied in stress testing credit risk for different countries:

Boss (2002) applied a credit risk model on Austrian corporate sectors' aggregate data, corporate and households. The expected and unexpected losses for a defined credit portfolio were estimated, conditional on the current macroeconomic conditions. He used a stress scenario in both cases.

Virolainen (2004) developed a macroeconomic credit risk model for the Finish sector using industry specific default rates. Default rates were modeled using the logistic function and a seemingly unrelated regression model was used to determine the influence of macroeconomic variables on sectoral default rates. The variables with the best explanatory power were GDPgrowth rate, sectoral indebtedness and interest rates. In order to estimate default rates the dynamic of macroeconomic factors was described using autoregressive of order 2 processes.

Latent factor model of Merton's type for the Czech economy is used in **Jakubik (2007**). Also Jakubik & Schmieder (2008) model the default rate that is measured by the inflow of non performing loans (NPLs) The model was applied to household and corporate sectors for the Czech Republic and Germany.

Kattai (2010) investigated the credit risk model that has been developed for the Estonian banking system. The non-performing loans and loan loss provisions of the four largest banks and the rest of the banking sector have been modeled conditional on the underlying economic conditions: economic growth, unemployment, interest rates, inflation, indebtedness and credit growth. The model distinguishes between consumption credit, mortgage clients and corporate loans.

Definition of concepts

Credit risk can be defined as the risk of changes in the value of the credit portfolio determined by an unexpected changed in the credit quality(**market to market approach**)

Credit risk also represents the risk of changes in the value of the credit portfolio triggered by the default of the counterparty)(**default mode approach**).

Default risk is the risk that a counterparty does not honor his obligations. Basel Committee considers that a default has occurred when one of the 2 events has occurred :
a)the bank considers that the obligator it is unlikely to pay its credit obligations without recourse by the bank
b)the obligator is past due more than 90 days on any material credit obligations to the bank

Stress testing is defined by BIS(2000) as a series of “techniques used by the financial institutions to gauge their potential vulnerability to exceptional but plausible events”.

Assumptions
-In the current developed model of credit risk for the Romanian corporate portfolio, will be used the default model approach;
-It will be considered default risk the case in which the obligator is past due more than 90 days on his payment obligations

Methodology for modeling the relationship between default rates and macroeconomic variables I

- The default rate for each sector will be calculated as the ratio of non performing loans(NPL) in total outstanding loans.
- The corporate sectors considered are represented by Agriculture, Industry, Construction and Services
- As NPL rate rises, banks need more provision to cover losses. Therefore, NPL can represent a measure of default risk
- Blaschke et al.(2001) show that NPL ratio itself can be treated as a default frequency measure. This is valid in case of normal distribution of credit exposures and when there is no time variance in the recovery rate
- In each case the default rate will be modeled by the logistic function:

$$p_{i,t} = \frac{1}{1+e^{y_{it}}}$$

where $p_{i,t}$ represents the NPL rate of sector i at time t

$$y_{i,t} = \ln\left(\frac{1-p_{i,t}}{p_{i,t}}\right)$$

where $y_{i,t}$ represents a macroeconomic index that is determined by a number of exogenous factors

Methodology for modeling the relationship between default rates and macroeconomic variables II

- The logit transformation of the NPL ratio for each sector *i* at time *t* $y_{i,t}$ will be considered as dependent variable
- The variable will be regressed against a set of explanatory factors in case of each corporate sector *i* at time *t* represented by $x_{i,t}$
- a set of regression coefficients β_i that determine the direction and the impact of each macroeconomic variables on the specific sector index will be estimated

$$x_{i,t} = (x_{i,1,t}, x_{i,2,t}, x_{i,3,t} \dots x_{i,n,t})$$

$$\beta_i = (\beta_{i,0}, \beta_{i,1}, \beta_{i,2} \dots \beta_{i,n})$$

- $$y_{i,t} = \beta_{i,0} + \beta_{i,1} x_{1,i,t} + \beta_{i,2} x_{2,i,t} + \beta_{i,3} x_{3,i,t} + \dots \beta_{i,n} x_{i,n,t} + \varepsilon_{i,t} \quad (1)$$

$$\varepsilon_{i,t} \sim N(0, \sigma_{i,\varepsilon}) \qquad \varepsilon_t \sim N(0, \Sigma_\varepsilon)$$

- The systematic component of the credit risk will be captured by $x_{i,t}$
- The industry specific surprise will be captured by the error term

Data

- Quarterly data was used in case of the logit transformation of NPL ratios for Agriculture, Industry, Constructions and Services, and macroeconomic variables covering the period 2006Q1-2012Q4
- All variables were tested for stationarity, the logit transformation proved to have an unit root and first difference was used
- The explanatory variables considered, the expected sign of the correlation between macroeconomic variables on default rates , as well as the transformations applied are explained below

Category	Expected sign	Variable	Motivation	Transformation applied
Cyclical indicators	+	Volume index of GDP	Banks are said to behave in a procyclical with respect to their lending	seasonally adjusted,logarithmated
		Nominal GDP growth rate		seasonally adjusted, first difference was used
		Output gap		first difference was used
Banking system	–	Indebtedness ratio industry specific	Firms which are highly indebted are more sensitive when the	first difference was used in case of
External indicators	–	Exchange rate	A real appreciation adversely affects the tradable goods sector, and within this sector it is likely to affect firms	first difference was used
	+	Foreign Direct Investments	Positive and significant correlation between FDI and economic growth has been determined (Bende-Nabende and Ford (1998); Soto (2000); Lu and Liu (2005))	amounts were transformed to lei, ln transformation was applied, first difference was used
	+	Exports	Exports should have a positive effect on economic growth	ln transformation, first difference
Interest rate indicators	-	loan interest rate	As loan interest rate increases, the cost supported by firms increase and default rate will rise	first difference was used
	-	ROBOR3M	The majority of loans taken by the corporations are variable-rate and linked to short-term market interest rates. Interest rate represents a cost for firms	first difference was used
Price indicators	-	Energy price for industrial producers	An increase in the energy price implies a decrease in firms profits and triggers an increase in default rates	logartithmated, first difference was used

Estimation results- modeling the relationship between default rates and macroeconomic variables I

Results for univariate models(OLS estimates)

	Agriculture		Industry		Construction		Services	
	Coefficient	R^2	Coefficient	R^2	Coefficient	R^2	Coefficient	R^2
Cyclical indicators								
Volume index GDP	**(2.731136)***	**0.113391**	**(2.238596)****	**0.296304**	**(3.347545)****	**0.295468**	**(1.699109)*****	**0.210752**
GDP growth rate	1.117586	0.009158	1.708403	0.08324	2.257573	0.064819	(1.834737)*	0.118533
GDP output gap	0.761131	0.003719	1.627469	0.066132	2.073751	0.047882	(2.122587)**	0.138886
Price stability indicators								
Energy price	-5.499083	0.006365	-4.416766	0.01597	10.21029	0.038059	2.941431	0.008745
Financial leverage								
Indebtedness AGR	-8.037024	0.083093						
Indebtedness IND			**(-5.486734)***	**0.401212**				
Indebtedness CONSTR					-0.876263	0.010665		
Indebtedness SERV							**(-2.565825)***	**0.126324**
Interest rate indicators								
Loan interest rate in RON	-0.088335	0.002974	-0.336989	0.000508	-0.380569	0.000289	-0.498044	0.00137
ROBOR3M	-0.069087	0.000009	1.37827	0.014637	2.441463	0.020481	**(3.378350)***	**0.108577**
External variables								
FDI	2.21588	0.042252	**(2.096792)****	**0.147151**	**(2.786705)***	**0.115906**	0.480982	0.00956
Exchange rate	**(-0.970346)***	**0.091069**	-0.432162	0.068569	**(-1.248340)****	**0.255137**	-0.31027	0.2957
Exports	0.511803	0.002282	0.767039	0.019932	-1.096902	0.018177	0.717986	0.021562

*, ** and *** show significance at 10%, 5% respectively 1% level

- In order to establish which among the macroeconomic factors can better explain the change in the macroeconomic index for each sector, respectively the default rate, univariate regressions were performed.
- The same approach was also used by Boss(2002) for the Austrian Central Bank(OeNB)
- Dependent variable represented by the logit transformation of default rate was regressed against each explanatory variable considered in case of each sector.

Estimation results- modeling the relationship between default rates and macroeconomic variables II

Results for multivariate models(Seemingly unrelated regression (SUR)estimates)

	Agriculture	Industry	Construction	Services
Constant	**-15.010489**	**-6.575161**	**-14.212642**	**-7.085638**
t statistic	-2.303382	-2.536065	-3.246815	-2.592244
p-value	0.031086	0.018821	0.0037	0.016629
GDP index volume	**3.24112**	**1.605673**	**3.020099**	**1.602111**
t statistic	2.296565	2.889473	3.173707	2.725339
p-value	0.031537	0.008508	0.004396	0.012355
Indebtedness	**-7.521842**	**-3.087533**	**-3.176985**	**-1.422226**
t statistic	-2.253957	-4.059508	-2.759578	-1.491269
p-value	0.034496	0.000522	0.011436	0.150091
FDI		**0.99335**	**2.808621**	
t statistic		2.135959	2.404613	
p-value		0.04406	0.025046	
Loan interest rate	**-6.961242**			**-2.691319**
t statistic	-1.871157			-1.711241
p-value	0.074683			0.101102
	0			1
R^2	0.2471	0.5568	0.4516	0.3695
DW	2.5239	1.7497	1.7558	0.8537

- Based on the results of univariate regression, multivariate models were created in order to trace the development of default rates

- The estimation of the link between the macroeconomic index for the four industries and a set of explanatory variables will be performed using SUR method.

- The same method of estimation was also employed by Virolainen (2004) for the Central Bank of Finland.

- SUR estimates were used as to control for the contemporaneous correlation in the residuals induced by correlations in the dependent variables

Estimation results- modeling the relationship between default rates and macroeconomic variables I

Interpretation of results from SUR estimates

- The volume index GDP, the loan interest rate, foreign direct investments and the industry-specific measures of corporate indebtedness have the expected sign in all equations

- An increase in the cyclical indicator affects positively the demand for goods that companies produce, which in turn increases their profits and creditworthiness and leads to a decline in default rates.

- Firms which are highly indebted are more sensitive when the economy slows down. To honor the obligations to creditors, are obligated to sell assets and reduce deposits. The asset value will fail and the probability of default will increase.

- FDIs are considered to impact economic growth by functioning as an engine of technological diffusion coming from the developed countries to the target ones. FDIs are significant only in the case of Industry and Construction sector, as at the end of 2011, they were channeled primarily to the industry sector (44%) and also significant FDIs were attracted by construction and real estate(10.7%)

- The loan interest rate effect on default rates is positive, as higher interest rates increase firms' costs of loans, and that can cause problems in their repayment

- The R squared value suggest that the specification of the static model is satisfactory, poor results are obtained in the case of Agriculture sector, this can be explained by the fact that the sector has a small contribution in the Value Added, it is difficult to distinguish between households farming and firm type farming

- Also, in case of Services sector, the explanatory power of the volume index, indebtedness ratio and loan interest rate is lower, due to the heterogeneity of activities comprised

Estimation results- modeling the relationship between default rates and macroeconomic variables III

Results for multivariate models(OLS estimates)

	Agriculture	Industry	Construction	Services
Constant	**-16.42578**	**-5.421065**	**-17.1524**	**-5.461624**
t statistic	-2.381255	-1.918238	-3.473678	-1.867625
p-value	0.0259	0.0676	0.0021	0.0752
GDP index volume	**3.555045**	**1.46634**	**3.668408**	**1.37668**
t statistic	2.378779	2.471662	3.417686	2.189766
p-value	0.0261	0.0213	0.0024	0.0394
Indebtedness	**-11.14294**	**-4.650607**	**-3.407972**	**-3.119806**
t statistic	-2.162289	-4.009153	-2.354578	-2.284199
p-value	0.0412	0.0005	0.0275	0.0324
FDI		**1.034203**	**2.003925**	
t statistic		1.335084	1.422438	
p-value		0.1949	0.1683	
Loan interest rate	**-6.044927**			**0.0324**
t statistic	0.2793			0.0324
p-value	0.1533			0.0243
	0			1
R^2	0.27398	0.555441	0.448615	0.379363
DW	2.483822	2.044356	1.61103	0.861126

Correlation matrix residuals SUR

	Agriculture	Industry	Construction	Services
Agriculture	1	0.7254	-0.0675	0.3965
Industry	0.7254	1	0.0743	0.6631
Construction	-0.0675	0.0743	1	0.3615
Services	0.3965	0.6631	0.3615	1

Correlation matrix residuals OLS

	Agriculture	Industry	Construction	Services
Agriculture	1	0.8097	-0.0450	0.3979
Industry	0.8097	1	0.0394	0.6724
Construction	-0.0450	0.0334	1	0.3613
Services	0.3379	0.6724	0.3613	1

- Estimates were also performed by means of OLS and overall the results obtained don't differ significantly.
- Coefficients obtained displayed the same sign in both methods of estimation
- Also, the correlation matrix of residuals was computed in both cases, correlation coefficient among the 4 sectors were lower in case of the SUR estimation

Estimation results- modeling the relationship between default rates and macroeconomic variables IV

Results for multivariate models(OLS estimates) when a lagged term of the dependent variable is introduced

	Agriculture	Industry	Construction	Services
Constant	**-12.5378**	**-5.37512**	**-14.97493**	**0.985542**
t statistic	-2.440652	-1.770475	-2.694203	1.740828
p-value	0.0236	0.0912	0.0136	0.0957
GDP index volum	**2.712991**	**1.46634**	**3.18957**	
t statistic	2.438717	2.471662	2.641474	
p-value	0.0237	0.0343	0.0153	
Indebtedness	**-8.175922**	**-4.690889**	**-2.975118**	**-3.360284**
t statistic	-1.714678	-3.79793	-1.761912	-2.05783
p-value	0.1011	0.0011	0.0926	0.0516
FDI		**1.072657**	**2.23495**	
t statistic		1.171507	1.555383	
p-value		0.2545	0.1348	
Exchange rate	-0.9832			
t statistic	-1.859489			
p-value	0.077			
Robor 3M				**3.113018**
t statistic				1.952136
p-value				0.0638
AR(1)	**-0.36445**	**-0.02905**	**0.147134**	**0.43855**
t statistic	-1.73459	-0.118944	0.617202	2.174604
p-value	0.0975	0.9065	0.5437	0.0407
R^2	0.340528	0.588347	0.466615	0.40924
DW	1.891562	1.88582	1.965496	1.616296

- It has been determined that the logit transformation of default rates can be modeled using an AR(1) process
- Due to the poor explanatory power of the model in case of Agriculture and Services sector, the lagged dependent variable was also introduced in the multivariate models.
- In case of Industry and Construction sectors AR term proved to be insignificant, although the logit transformations of NPL ratios seemed to be persistent and influenced by past values.
- An explanation might me that in the model is introduced the indebtedness ratio calculated as total outstanding loans of an industry to annualized value added of the industry, that contains already a lag of 4 quarters and might explain the fact that dependent variable is influenced by the past information.
- In case of Agriculture and Services the autoregressive term was significant
- However, the goodness of fit didn't show a significant improvement respective to the first model.

Methodology and estimates for modeling the evolution of each macroeconomic variable

- The dynamics of each macro variable will be obtained by using ARMA (p,q)models

$$x_{j,t} = \alpha_{j,0} + \alpha_{j,1}x_{j,t-1} + \alpha_{j,2}x_{j,t-2} + \ldots\alpha_{j,p}x_{j,t-p} + \delta_{j,1}\mu_{j,t-1} + \ldots\delta_{j,q}\mu_{j,t-q} \qquad (2)$$

$$\mu_{j,t} \sim N(0, \sigma_{j,\mu}) \qquad \mu_t \sim N(0, \Sigma_\mu)$$

	Volume index GDP	Indebtedness Agriculture	Indebtedness Industry	Indebtedness Constructions	Indebtedness Services	FDIs	Interest on loans
C	**4.617895**	**0.007398**	**0.328636**		**0.35283**	**0.029147**	
t statistic	(235.2158)***	(6.185845)***	(30.49263)***		(36.20754)***	(10.33939)***	
AR(1)	**1.521505**		**1.243987**				**0.416343**
t statistic	(10.25998)***		(6.647745)***				(2.317811)**
AR(2)	**-0.686778**		**-0.447387**		**0.584494**		
t statistic	(-4.680809)***		(-2.517247)***		(4.735112)***		
AR(3)						**0.452077**	
t statistic						(5.669456)***	
AR(4)				**-0.215753**			
t statistic				(-2.262306)***			
AR(5)							**-0.420023**
t statistic							(-2.324783)**
MA(1)					**0.470191**	**-0.933418**	
t statistic					(2.569220)**	(-9.076903)***	
MA(2)					**-0.522776**		
t statistic					(-2.771198)**		
MA(3)							
t statistic							
MA(4)		**-0.844506**		**0.969153**			
t statistic		(-10.63650)***		-38.77415			
R^2	0.901612	0.331486	0.788258	0.765844	0.78478	0.297616	0.257851
DW	1.820825	2.568922	1.987905	1.394233	1.80895	1.340307	1.856992

Methodology for determining the variance-covariance structure

- Next, the correlation structure of the model is defined.

- The model that regresses the logistic transformation of the default rate for each industrial sector on a set of macroeconomic variables, together with the model which determines the evolution of each explanatory variable form a system of equations.

- The vector of residuals will of dimension *(i+j)*x1, where *i* represents the number of industrial sectors and j the number of macroeconomic variables. The variance covariance matrix of the system will be of dimension *(i+j)x(i+j).*

$$E = \begin{pmatrix} \varepsilon \\ \mu \end{pmatrix} \qquad \Sigma = \begin{bmatrix} \Sigma\varepsilon & \Sigma\varepsilon,\mu \\ \Sigma\varepsilon,\mu & \Sigma\mu \end{bmatrix} \qquad (3)$$

- The covariance matrix of the system is determined as to account for the interdependences between macroeconomic shocks and their impact on the macroeconomic indexes, as well as the correlation between sectors.

- This assumption is important when constructing stress testing scenarios, as the shock introduced by one macroeconomic variable may imply also a negative impact on another variable, if the correlation between the two variables is positive,

Estimation of system correlation matrix

- The highest correlation coefficient is between Agriculture and Industry generate a correlation coefficient of 0.7254, the cause of this high interdependence is due to multiple reasons: agriculture supplies inputs to industry, while industry supplies industrial inputs, such as fertilizer, pesticides, machinery etc. to the agriculture sector.
- A high correlation is also among the Services and Industry of 0.635 due to the main previous reasons.
- In this case the correlation coefficients are much lower varying from -0.465 to a maximum value of 0.453.
- The direction of the correlations are in line with the economic theory, as the correlation between volume index GDP and FDIs is positive, while the one between economic growth and loan interest rate is negative.
- Mixed results are obtained in case of correlations between economic growth and indebtedness ratio

	Agriculture	Industry	Construction	Services	Index GDP	Indeb AGR	Indeb IND	Indeb CONSTR	INDEB SERV	FDI	Interest
Agriculture	1	0.725	-0.07	0.372	0.238	-0.29	-0.308	-0.028	-0.289	0.162	0.011
Industry	0.725	1	0.073	0.635	0.097	-0.333	-0.19	-0.081	-0.376	0.168	0.106
Construction	-0.07	0.073	1	0.367	0.111	0.051	-0.165	0.006	-0.048	0.101	-0.317
Services	0.372	0.635	0.367	1	0.326	0.072	-0.426	-0.137	-0.409	0.098	-0.107
Index GDP	0.238	0.097	0.111	0.326	1	**0.153**	-0.398	**0.379**	-0.252	0.212	-0.207
Indeb AGR	-0.29	-0.333	0.051	0.072	0.153	1	-0.099	0.156	-0.048	-0.203	-0.286
Indb IND	-0.308	-0.19	-0.165	-0.426	-0.398	-0.099	1	-0.036	0.315	-0.288	0.388
Indeb CONST	-0.028	-0.081	0.006	-0.137	0.379	0.156	-0.036	1	-0.117	0.453	0.108
INDEB SERV	-0.289	-0.376	-0.048	-0.409	-0.252	-0.048	0.315	-0.117	1	-0.465	0.152
FDI	0.162	0.168	0.101	0.098	0.212	-0.203	-0.288	0.453	-0.465	1	0.024
Interest	0.011	0.106	-0.317	-0.107	-0.207	-0.286	0.388	0.108	0.152	0.024	1

Methodology - estimation of default rates

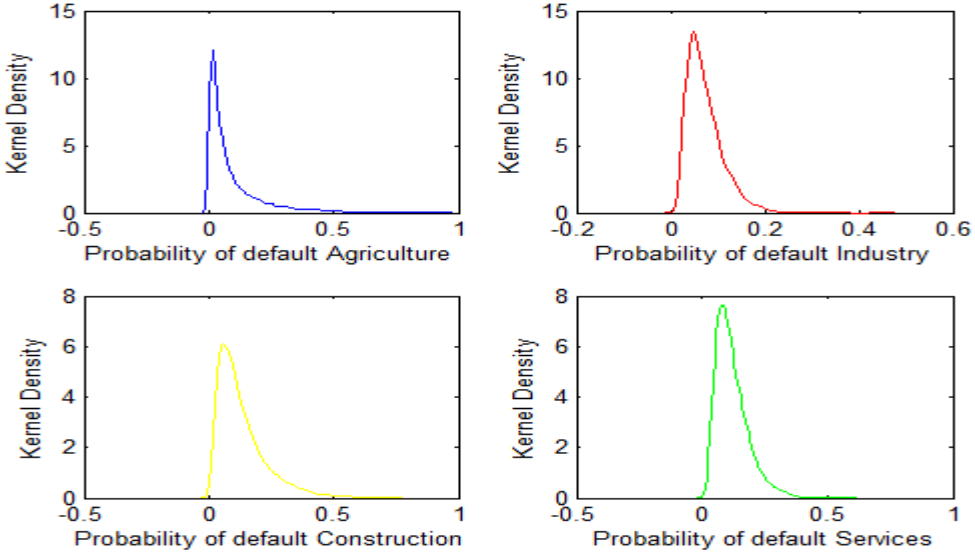
- In order to estimate default rates per sector for 1 year ahead a Monte Carlo simulation will be performed:
- First the variance covariance matrix of the system is decomposed into a lower and upper triangular matrices by using Cholesky decomposition

$$\sum = A' A$$

- Then a vector of Z *(i+j)**1 of standard normal variables is drawn
- These independent random variables are transformed into correlated normal variables by multiplying Z with A, i.e. Z*=AZ
- The results returned by this vector will represent the value of residuals for the *i* sectoral indices and *j* ARMA structures
- One step ahead values for the exogenous variables are forecast and the residuals are added to simulate the new values
- With the simulated values of macro fundamentals and adding the innovations of sectoral indices the new value of macroeconomic indices will be computed and also the default rates
- As the logit transformation of the default rates was nonstationary, the first difference was used. As a result in order to calculate the NPL ratios, initial values were inputed

Default rates estimations-baseline scenario

Kernel density distributions of default rates for the 4 sectors over 1year horizon



Characteristics of default rates distribution

	Agriculture	Industry	Construction	Services
mean	0.094611336	0.073113	0.131627	0.120859
stdev	0.121972347	0.038816	0.101331	0.065323
50% quantile	0.047314076	0.064341	0.103381	0.107001
90% quantile	0.249873558	0.125289	0.265274	0.207186
99% quantile	0.580667776	0.196224	0.499058	0.332849

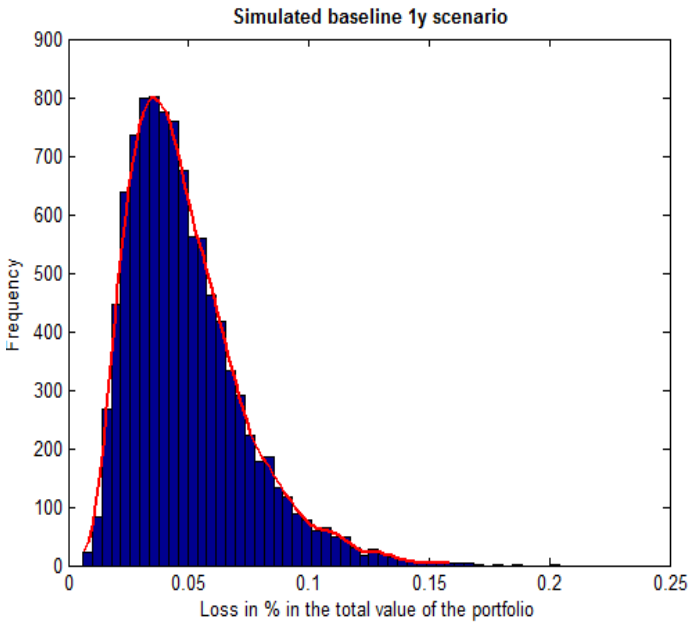
-The shapes of the distributions are skewed to the right, as expected, mainly because default rate is nonlinearly related to the macro variables

-This implies that the probability of default in times of high stress increases substantially more than in normal times.

-The probability of default , approximated by the median of the distribution, varies between 4% to 10%

Loan loss distribution I

-The sector specific probabilities of default will be used to determine the loss distribution of an arbitrary built portfolio
-A hypothetical portfolio will be build consisting of 3,000 loans
-At the construction of the credit portfolio there were considered the percentage distribution of corporate loans by industry
-Then the exposures for each loan was drawn randomly, uniformaly distributed for each business sector in equal numbers. In case of each sector, random exposures were drawn until the aggregated corresponding amount for each sector was reached as well as the number of loans
-The simulated probabilities of default are than applied to individual exposures in the arbitrary portfolio and its loss distribution is estimated over a one year time horizon
- A fixed recovery rate will be used, loss given default will be set to 0.45
-The expected and unexpected losses will be computed as the 50% and 99.9% percentiles of the loss distribution



Loan loss distribution II

Expected loss= median of the loss distribution

$$ExpectedLoss_i = \sum_i EAD_i PD_i LGD_i$$

Value at Risk is estimated by taking the relevant quantile q_α of the conditional portfolio distribution:

$VaR_\alpha = q_\alpha$

Unexpected loss= VaR_α – Expected loss

the 99.9th percentile of the simulated loss distribution implies that another 11.1% of the overall corporate credit exposure would be required as a capital buffer to avoid bank default in 99.9 cases out of 100.

	Baseline scenario
Expected loss	**0.044060715**
Unexpected loss(99.9%)	**0.111252812**

Stress testing- worst case historical scenarios I

- at first the extreme residuals resulted from ARMA estimates are determined and divided at their standard deviation in order to be standardized
- the standardized residuals are replaced with the standard normal variables in the vector defined previously which will be multiplied with the decomposed matrix of variance covariance and added in the estimates of macroeconomic variables
- in some cases, historical worst case values for some variables do not generate bad outcomes for the entire model. This is caused by the correlation structure between variables.

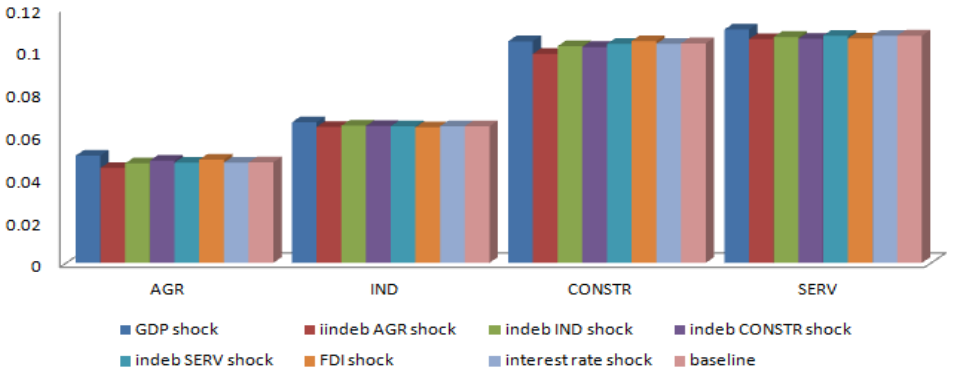
Standardized residuals	Extreme values	Standard deviation	Standardized
Index_gdp	-0.041119971	0.021322352	-1.928491377
Indeb_agr	0.0188	0.013383035	1.4059
Indeb_ind	0.0295	0.012407779	2.3815
Indeb_constr	0.1697	0.0394	4.3097
Indeb_serv	0.0357	0.01993949	1.7884
FDI	-0.0969	0.037732242	-2.5675
Loan_interest	0.0354	0.011900212	2.9733

Extreme values
-General cyclical shock: Fall in the GDP by 11.61% (observed in 2009Q1 due to the financial turmoil)
- Agriculture Indebtedness ratio shock: Increase of indebtedness of 5.55%(observed in 2012Q3)
-Industry Indebtedness ratio shock: increase of indebtedness of 9%(2008Q1)
-Construction Indebtedness ratio shock: increase of indebtedness of 73%(2008Q1)
-Services Indebtedness ratio shock:: increase of indebtedness of 8%(2007Q4)
-FDI shock : fall in foreign direct investments of 4%(2010Q2)
- Interest shock: increase of loan interest rate of 17%(2010Q1)

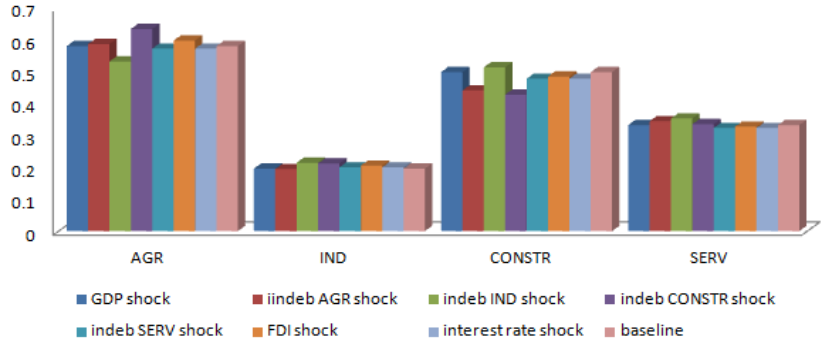
Stress testing- worst case historical scenarios II

-In some cases, historical worst case values for some variables do not generate bad outcomes for the entire model. This is because of the correlation structure between variables
For example, a bad outcome for one variable may also generate a good for another variable, and the final result may be better than the base scenario. This is due to the positive correlations that exist between index GDP variable and agriculture and construction indebtedness ratio. In case of this shocks, results obtained are better than in the baseline scenario

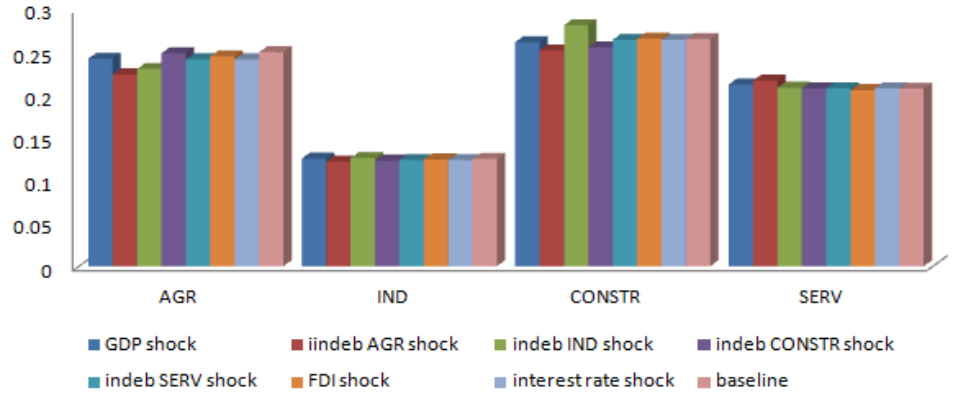
Changes in percentile of 50% for estimated default rates



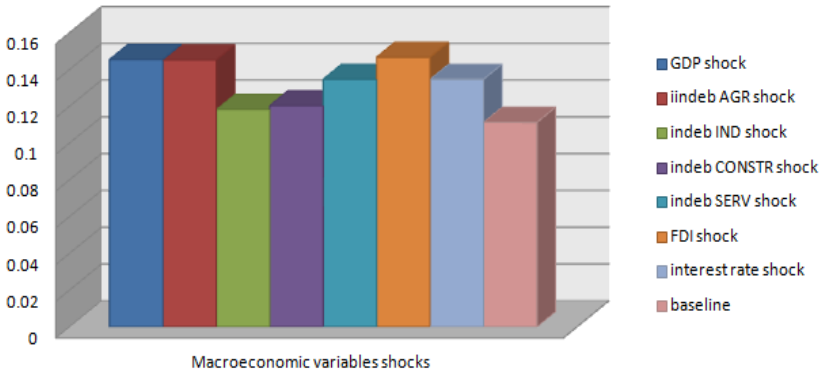
Changes in percentile of 99% for estimated default rates



Changes in percentile of 90% for estimated default rates



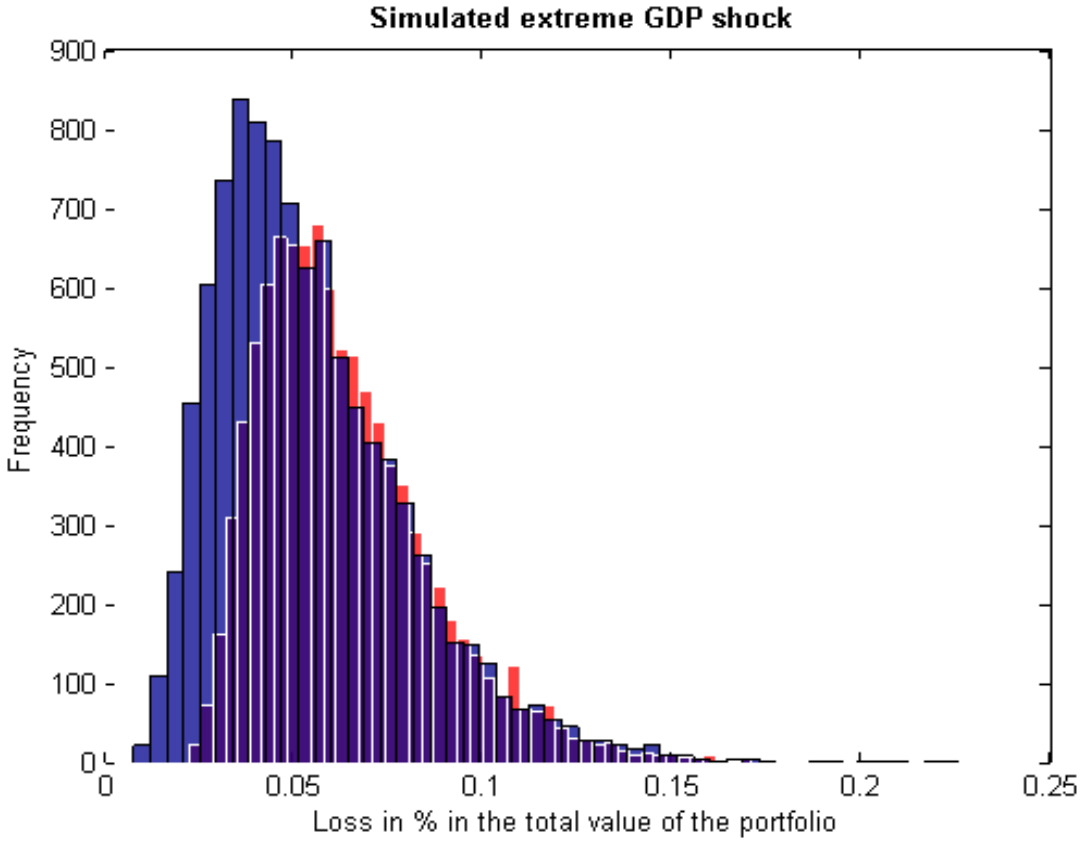
Changes in unexpected loss(%) for the corporate portfolio



Stress testing- extreme GDP shock

An extreme GDP shock will be considered: a fall in index GDP with 15% percentage change respective to previous period for four consecutive quarters

The evolution explained by the ARMA structure in case of the index GDP will be ignored, this is different then in the stress scenarios performed previously



Conclusions I

-It was found that determinants of defaults for the corporate sector on bank loans are volume index GDP, sector indebtedness, FDIs and interest rate on loans

-The effect of most of the variables is contemporaneous, as a fact we can state that default rates react quickly to modifications in macroeconomic variables

-Construction of a parsimonious model with a small number of variables is useful in performing stress testing

-The sectoral credit risks are related to each other through codependence on macro variables, as well as the correlation between these variables

-The probability of default varies in a range from 4% to 10% and indicates the heterogeneity of debt repayment among different economic sectors

-Stress testing was applied to an arbitrarily build portfolios, considering the percentage distribution of corporate loans by industry . Expected and unexpected loss were determined for the baseline scenario, as well as for worst cases historical shocks introduced by the macroeconomic variables, or in the case of an extreme GDP index shock

-In some cases, historical worst case values for some variables do not generate bad outcomes for the entire model. This is because of the correlation structure between variables, while the results obtained in case of an extreme GDP shock proved to generate higher losses than in the baseline scenario

Conclusions II

Further developments:

-Incorporation of second round, feedback effects from the financial sector into the real economy

- Having developed a top down, macroeconomic approach, micro levels details are not captured

- Using industry specific cyclical indicators instead of aggregate ones

- Relax the assumption regarding the fixed LGD and consider it dependent on the output gap

- A disadvantage is represented by the fact that NPL ratio was used as a proxy for the default rate, as this is valid in case of normal distribution of credit exposures and when there is no time variance in the recovery rate. For further research, NPL ratio can be disentangled between the default rate(the probability of transition of performing loans to non performing) and the non operating loans from previous period that remained non performing

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