BUCHAREST ACADEMY OF ECONOMIC STUDIES
MSc. DOFIN

SOVEREIGN RISK

Quantification and Analysis

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OBJECTIVES

- **WHY did I chose to study sovereign risk?**
  - because of the increased interest in this type of risk following the recent financial crisis

- **HOW did i study sovereign risk?**
  - using the Contingent Claims Approach

- **Why this particular approach ?**
  - because it has the following advatages:

    - it is a forward-looking approach since it considers market data
    - it allows quantifying sovereign risk by computing several risk indicators
    - the model can be further used to study the links between different economic sectors (e.g.: public sector and banking sector)

METHODOLOGY (1)

❑ Theoretical background:

=> based on Merton (1974) credit risk model

=> methodology was first applied on corporates

=> subsequently applied on countries that have a significant amount of public debt in foreign currency

=> papers:

- Gray, Merton, Bodie (2003)
- Gapen, Gray, Lim, Xiao (2005)
- Gray, Merton, Bodie (2007)
- Keller, Kunzel, Souto (2007)

❑ Steps:

1. Construction of sovereign balance sheet
2. Establishment of the seniority of liabilities
3. Estimate the implicit value and volatility of sovereign assets
4. Computation of sovereign credit risk indicators
5. Robustness assessment of computed indicators

METHODOLOGY (2)

Step 1

ASSETS:

- Foreign reserves
- Net fiscal asset
- Value of public sector's monopoly on the issue of money
- Other assets

LIABILITIES:

- Foreign currency debt
- Local currency debt held outside of the Government and Monetary Authority
- Base money
- Guarantees

Step 2

Senior Claims => Foreign currency debt

Junior Claims (Sovereign equity) => Domestic currency debt + Base money

Distress Barrier = Short-term foreign currency debt + 1-year interest payments + half of Long-term foreign currency debt

Step 3

❖ solving the following system of nonlinear equations

$$\begin{cases} DCL = A \times N(d1) - DB \times e^{-rf \times t} \times N(d2) \\ DCL = \dfrac{\sigma_A}{\sigma_{DCL}} \times A \times N(d1) \end{cases}$$

$$d1 = \frac{\ln\left(\frac{A}{DB}\right) + \left(rf + \frac{1}{2} \times \sigma_A^2\right) \times t}{\sigma_A \times \sqrt{t}}$$

$$d2 = d1 - \sigma_A \times \sqrt{t}$$

Step 4

❖ sovereign credit risk indicators

- credit spread: $s = -\frac{1}{t} \times \ln\left(N(d2) + \frac{A}{DB \times e^{-rf \times t}} \times N(-d1)\right)$
- risk neutral default probability: $rnpd = N(-d2)$
- distance-to-default: $d2d = \frac{A - DB}{A \times \sigma_A}$

Step 5

❖ Spearman rank correlation

❑ Sovereign equity volatility

Case 1:

- volatility of domestic currency debt in foreign currency terms: $\sigma_{DD} = \sqrt{\sigma_{DD\_lc}^2 + \sigma_X^2 - 2 \times \rho_{DD\_lc,X} \times \sigma_{DD\_lc} \times \sigma_X}$
- volatility of base money in foreign currency terms: $\sigma_M = \sqrt{\sigma_{M\_lc}^2 + \sigma_X^2 - 2 \times \rho_{M\_lc,X} \times \sigma_{M\_lc} \times \sigma_X}$
- volatility of domestic currency liabilities:

$$\sigma_{DCL} = \sqrt{(\frac{M}{M+DD})^2 \times \sigma_M^2 + (\frac{DD}{M+DD})^2 \times \sigma_{DD}^2 + 2 \times \rho_{M,DD} \times \left(\frac{M}{M+DD}\right) \times \sigma_M \times (\frac{DD}{M+DD}) \times \sigma_{DD}}$$

Case 2: $\sigma_{DCL} = \sigma_{stock\_index}$

❖ references: Oshiro and Saruwatari (2005); Wang et al. (2012)

Case 3 and 4: $\sigma_{DCL} = x \times \sigma_{stock\_index}$

- x = size parameter; determined by minimizing MAPE : $MAPE = \frac{1}{m} \times \sum_{i=1}^{m} \left|\frac{s_i - CDS_i}{CDS_i}\right|$
- In *Case 4* the same size parameter was considered for all 3 countries

❖ in the last three cases *sovereign equity* did not include base money

❖ Principal Components Analysis

Figure no.6 – Variance explained by the first few principal components for the 3 periods analyzed

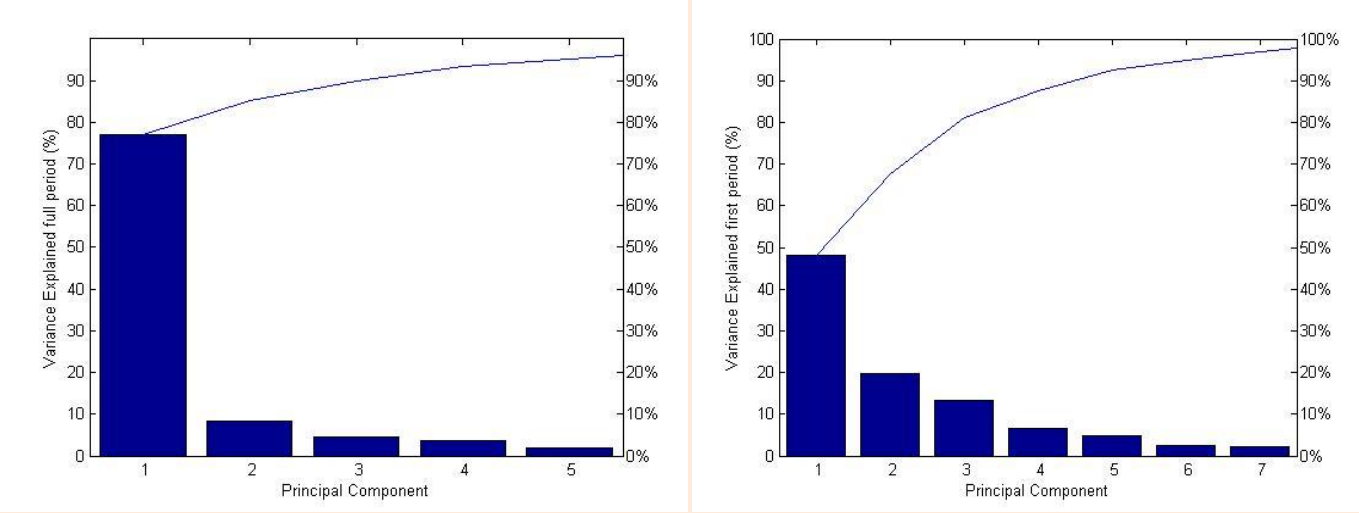


Table no.1 – Variance explained by the first few principal components for the 3 periods analyzed

	apr.2003 - mar.2013		apr.2003 - iun.2007		iul.2007 - mar.2013	
	%	% cum	%	% cum	%	% cum
PC1	76.91	76.91	48.07	48.07	80.95	80.95
PC2	8.34	85.25	19.71	67.78	7.27	88.22
PC3	4.52	89.77	13.29	81.08	4.67	92.89

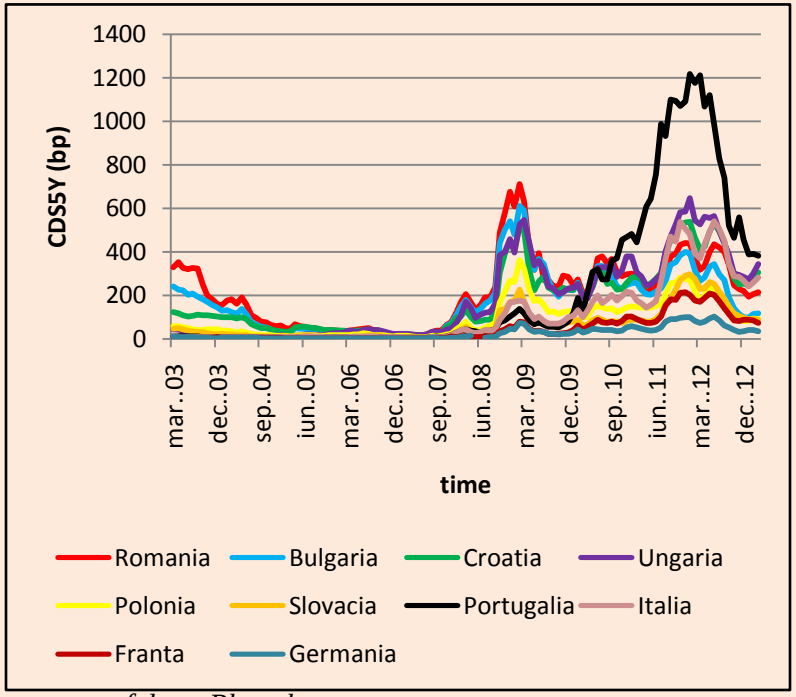
Table no.2 – Correlation of the first principal component with the US stock market for the 3 periods analyzed

		corelatie		p-value	
		SPX	VIX	SPX	VIX
PC1	apr.2003 - mar.2013	-0.7194	0.6281	2.13E-20	1.60E-14
	apr.2003 - iun.2007	-0.3298	0.2375	0.018094	0.093342
	iul.2007 - mar.2013	-0.7682	0.6897	1.32E-14	5.58E-11

Arguments for using stock index volatility as a proxy for sovereign equity volatility:

- computed market value of domestic currency liabilities is almost identical to its book value; another variable that reflects market evolution is needed;
- sovereign CDS spreads move together with US capital market indices, being determined by factors that are not necessarily country specific (PCA) => the need to include a financial market variable into the model;
- there is a significant negative correlation between stock indices and CDS spreads as shown in *Table no. 0*; because I try to obtain risk indicators that follow closely the evolution of CDS spreads as measure of sovereign risk, I think that the use of stock index data in the model is appropriate;

Figure no.7 – Evolution of 5-year sovereign CDS spreads for the 10 countries used in the PCA



source of data: Bloomberg

Table no. 0 – Correlation coefficients between CDS spreads and stock indices for each country

	rho	p-value
RO	-0.6219	1.36E-11
HU	-0.6809	2.30E-14
BG	-0.5197	5.78E-08

RESULTS (3)

Case 1

ROMANIA

- 2010M1 – 2013M1
- rolling window historical volatility: 60M

HUNGARY

- 2010M6 – 2013M2
- rolling window historical volatility: 77M

Figure no.8 – Model generated spread in Case 1 vs. CDS and EMBI Global

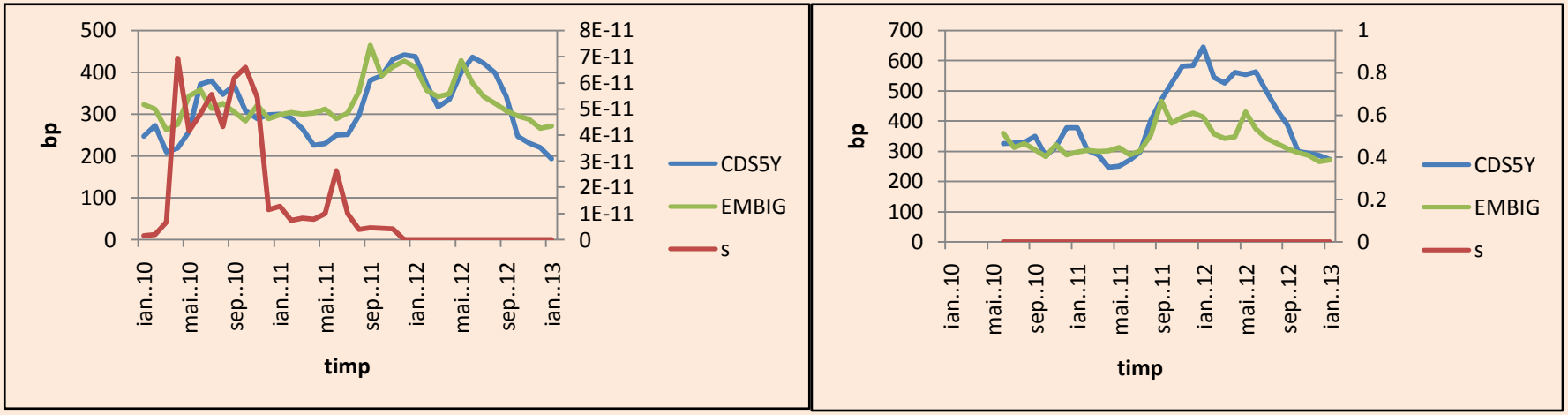


Table no.3 – Spearman rank correlation coefficients of the computed risk indicators with market data in Case 1

Romania	d2d	rnpd	s	Hungary	d2d	rnpd	s
CDS5Y	0.0581	0.0433	0.0443	**CDS5Y**	-0.2701	0.5	0.5
EMBIG	0.2221	-0.2405	-0.2419	**EMBIG**	-0.0846	0.5	0.5

RESULTS (4)

Case 2

ROMANIA and HUNGARY

- 2005M1 – 2013M1

BULGARIA

- 2005M10 – 2013M1

- rolling window for the annualized historical volatility of the stock index: 60 months

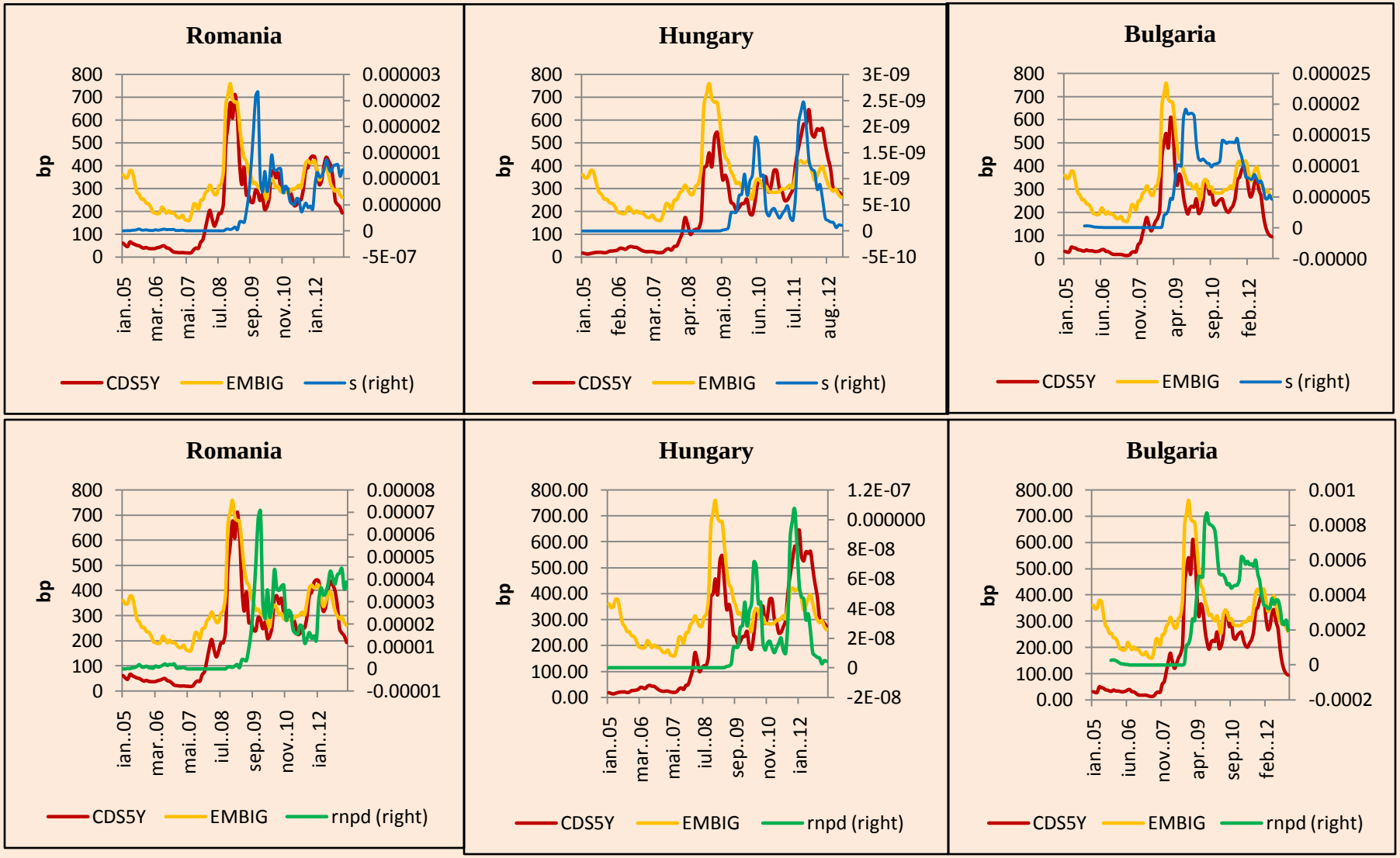
Table no.4 – Spearman rank correlation coefficients of the computed risk indicators with market data in Case 2

RO	d2d	rnpd	s	**HU**	d2d	rnpd	s
CDS1Y	-0.7626	0.6354	0.6863	CDS5Y	-0.738	0.8036	0.7902
RO	d2d	rnpd	s	**BG**	d2d	rnpd	s
CDS5Y	-0.6786	0.5855	0.6362	CDS5Y	-0.6799	0.6702	0.6656

- Correlation coefficients are statistically significant, have the right sign and have a high value
- The values of risk indicators are not as small as in the first case
- CONCLUSION: the results improved

RESULTS (5)

Figure no.9 – Model generated credit spreads and default probabilities vs. market sovereign CDS spreads in Case 2 for the three analyzed countries



Case 3

ROMANIA and HUNGARY

- 2005M1 – 2013M1

BULGARIA

- 2005M10 – 2013M1

- rolling window for the annualized historical volatility of the stock index: 60 months
- different size parameter for each country

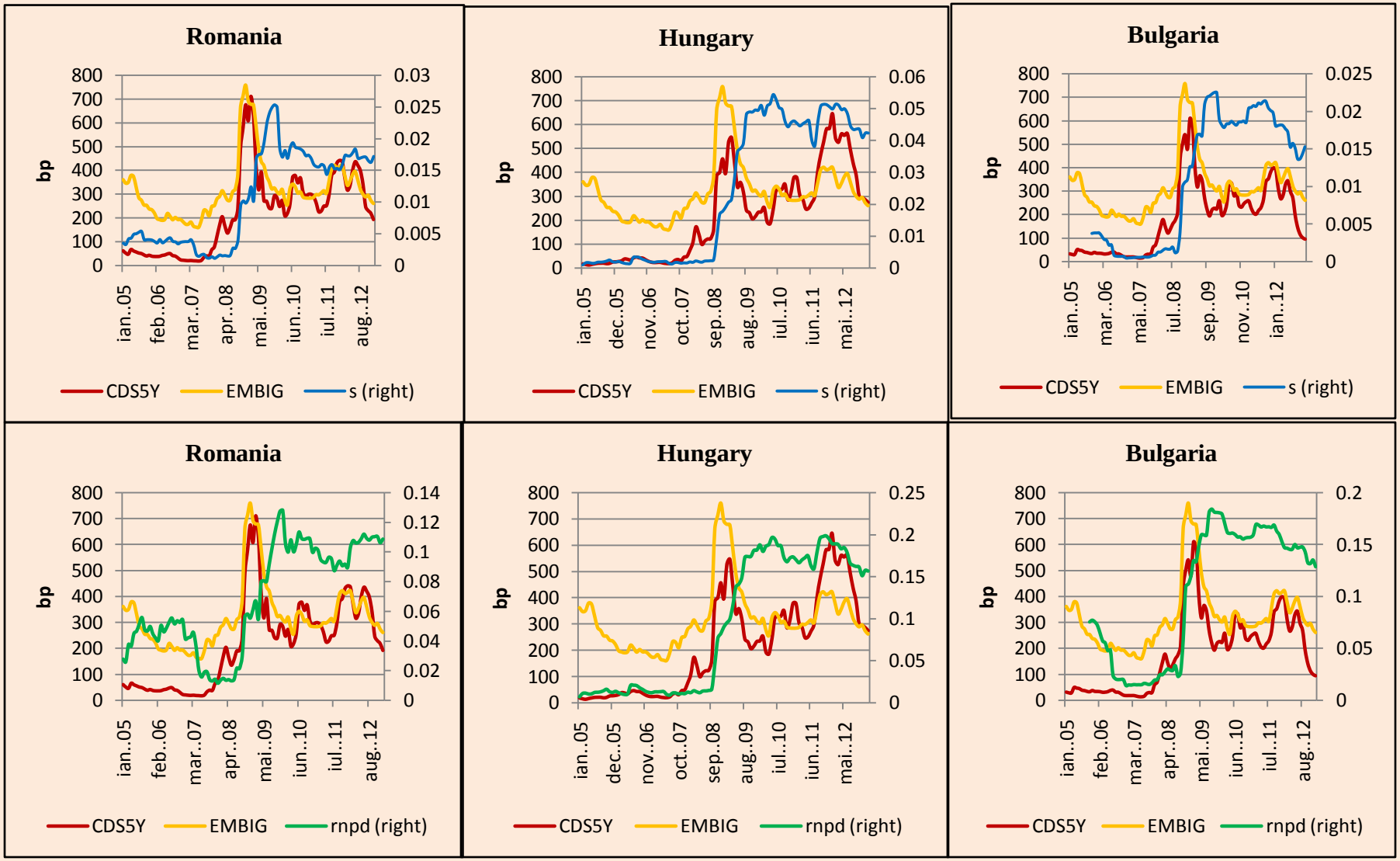
Table no.5 – Spearman rank correlation coefficients of the computed risk indicators with market data in Case 3

	total (2005M1 - 2013M1)			x	out-of-sample (2006M1 - 2013M1)		
	d2d	rnpd	s		d2d	rnpd	s
RO	-0.6732	0.648	0.6802	2.6	-0.6204	0.5968	0.6149
HU	-0.7792	0.7871	0.773	4	-0.7167	0.7402	0.7183
BG	-0.6735	0.6707	0.6756	2.5	-0.6676	0.6647	0.6684

- Again correlation coefficients are statistically significant, have the right sign and have a high value
- The value of sovereign credit risk spread is comparable with market data (quoted CDS spreads)
- The size parameter values are very close for Bulgaria and Romania

RESULTS (7)

Figure no.10 – Model generated credit spreads and default probabilities vs. market sovereign CDS spreads in Case 3 for the three analyzed countries



RESULTS (8)

Case 4

ROMANIA and HUNGARY

- 2005M1 – 2013M1

BULGARIA

- 2005M10 – 2013M1

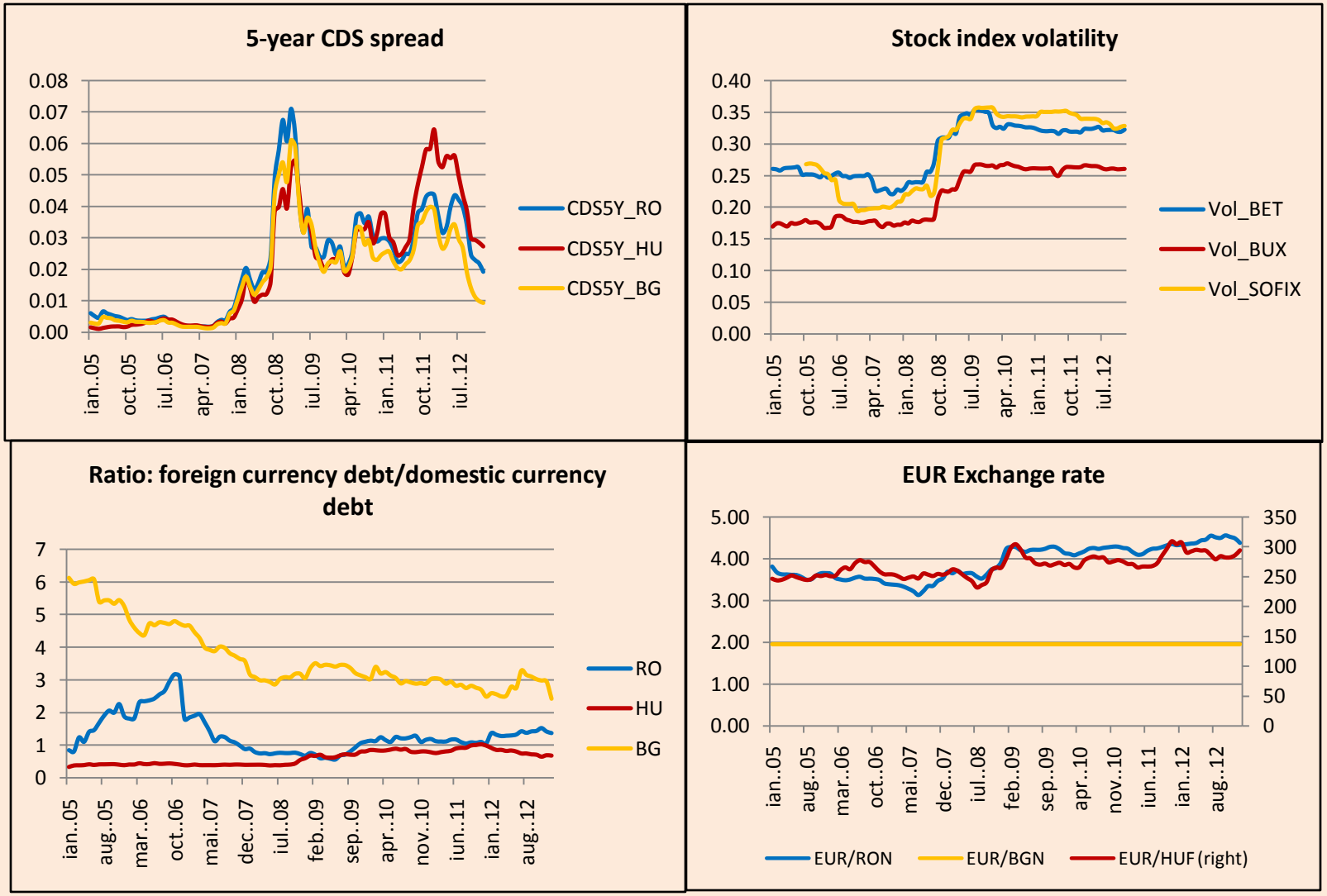
- rolling window for the annualized historical volatility of the stock index: 60 months
- same size parameter for each country: $x=2.6$

Table no.7 – Spearman rank correlation coefficients of the computed risk indicators with market data in Case 4, considering x=2.6

	total (2005M1 - 2013M1)			x	out-of-sample (2006M1 - 2013M1)		
	d2d	rnpd	s		d2d	rnpd	s
RO	-0.6732	0.648	0.6802	2.6	-0.6204	0.5968	0.6149
HU	-0.7442	0.789	0.7816	2.6	-0.664	0.7437	0.7319
BG	-0.6698	0.6709	0.6752	2.6	-0.5465	0.5432	0.5388

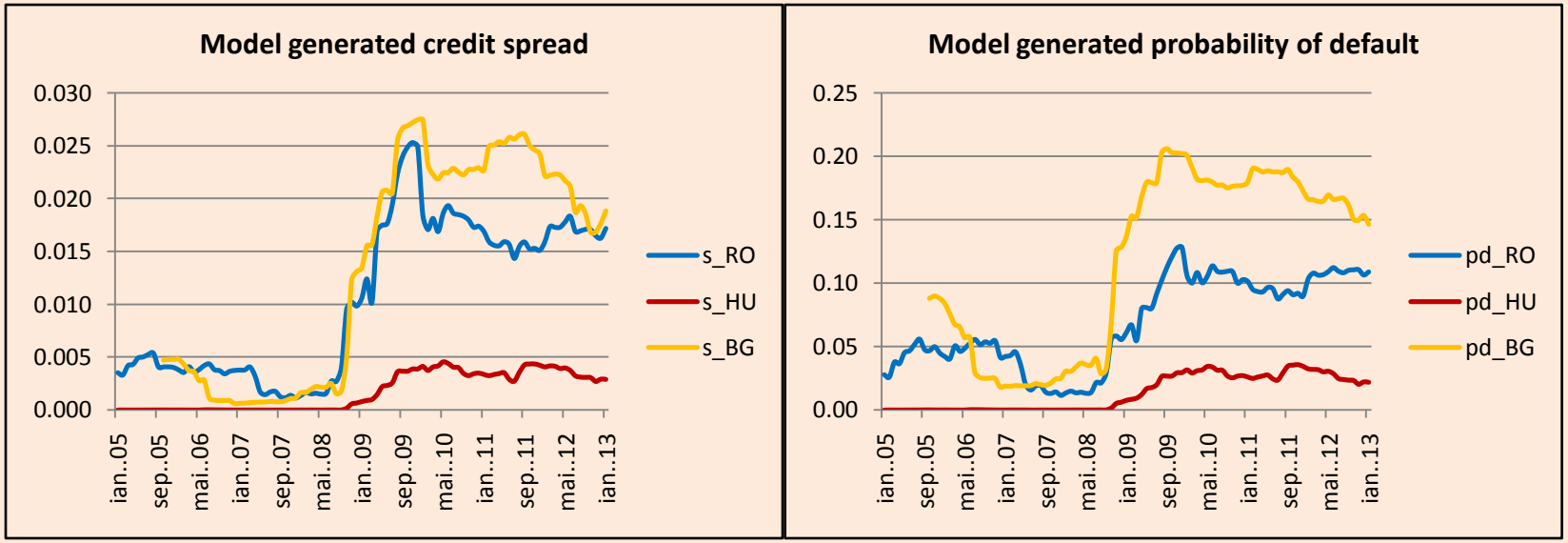
INTERPRETATIONS (1)

Figure no.11 – Data inputs for the three analyzed countries



INTERPRETATIONS (2)

Figure no.12 – Comparison of computed risk indicators by country in Case 4



- the above results capture only the data used, but not the market perception of risk: it is important to adjust the results with information from the market - determine and use the size parameter specific for each country
- Hungary has the lowest volatility of stock index and the lowest ratio of foreign-to-domestic currency debt, but is perceived as the riskiest one by the markets: starting with 2011 Hungary has the highest quoted CDS spreads and the S&P outlook associated to foreign currency debt is negative

INTERPRETATIONS (3)

Figure no.13 – Comparison of computed risk indicators by country in Case 3

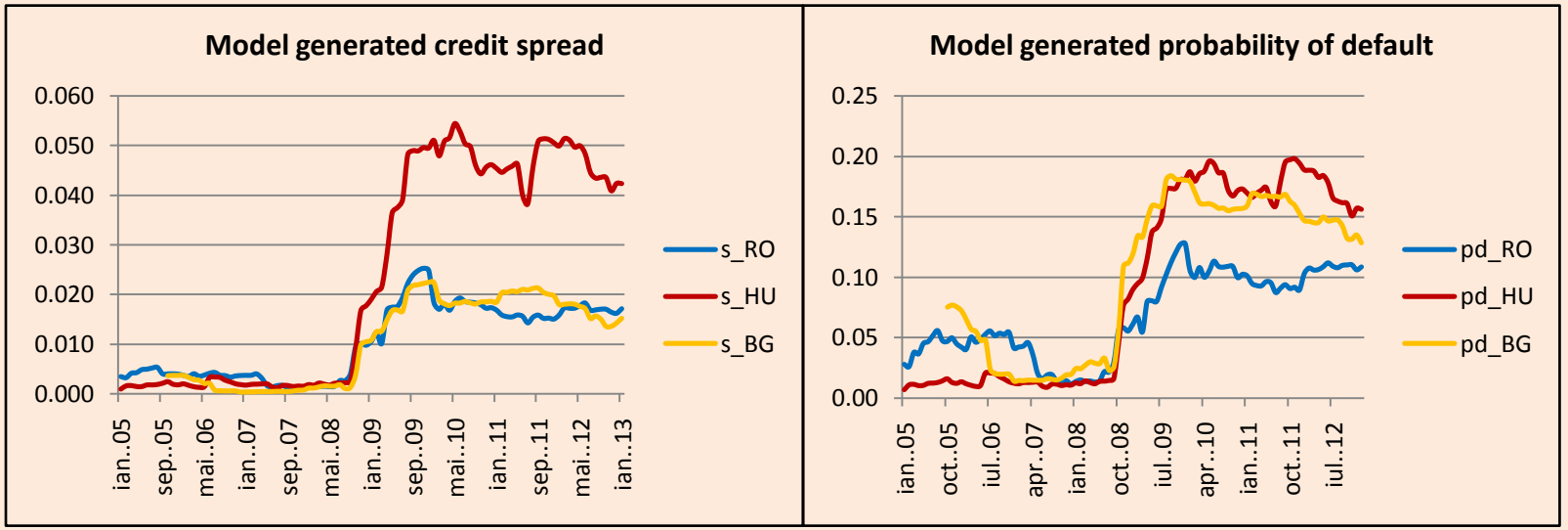


Table no.8 – S&P ratings

Romania		Hungary	
January 2005 - September 2005	BB+	January 2005 - June 2006	A-
September 2005 - October 2008	BBB-	June 2006 - November 2008	BBB+
October 2008 - present	**BB+**	November 2008 - March 2009	BBB
reaffirmed May 9, 2013		March 2009 - December 2011	BBB-
stable outlook		November 2011 - November 2012	BB+
Bulgaria		November 2012 - present	**BB**
October 2008 - present	**BBB**	reaffirmed March 21, 2013	
reaffirmed December 14, 2012		*negative outlook*	
stable outlook			

Source of data: akk.hu, mfinante.ro, countryeconomy.com

❖ *Case 3* generates the best results:

- in line with input data and market perception
- values of model generated spreads are the closest to market data (CDS spreads)

INTERPRETATIONS (4)

Figure no.14 – Comparison of cases

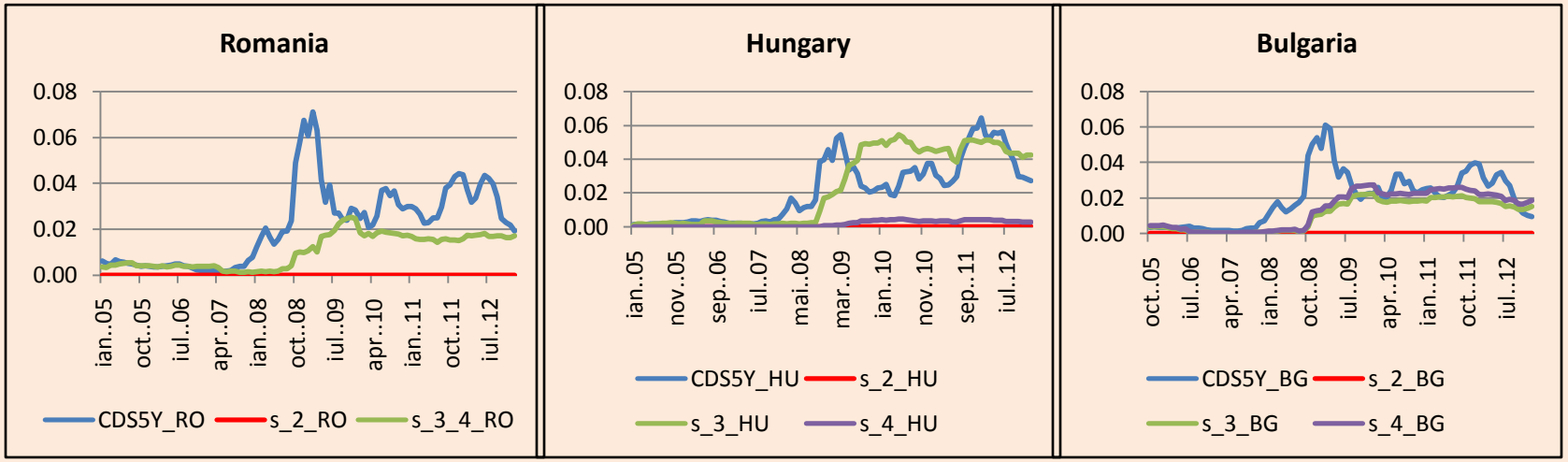


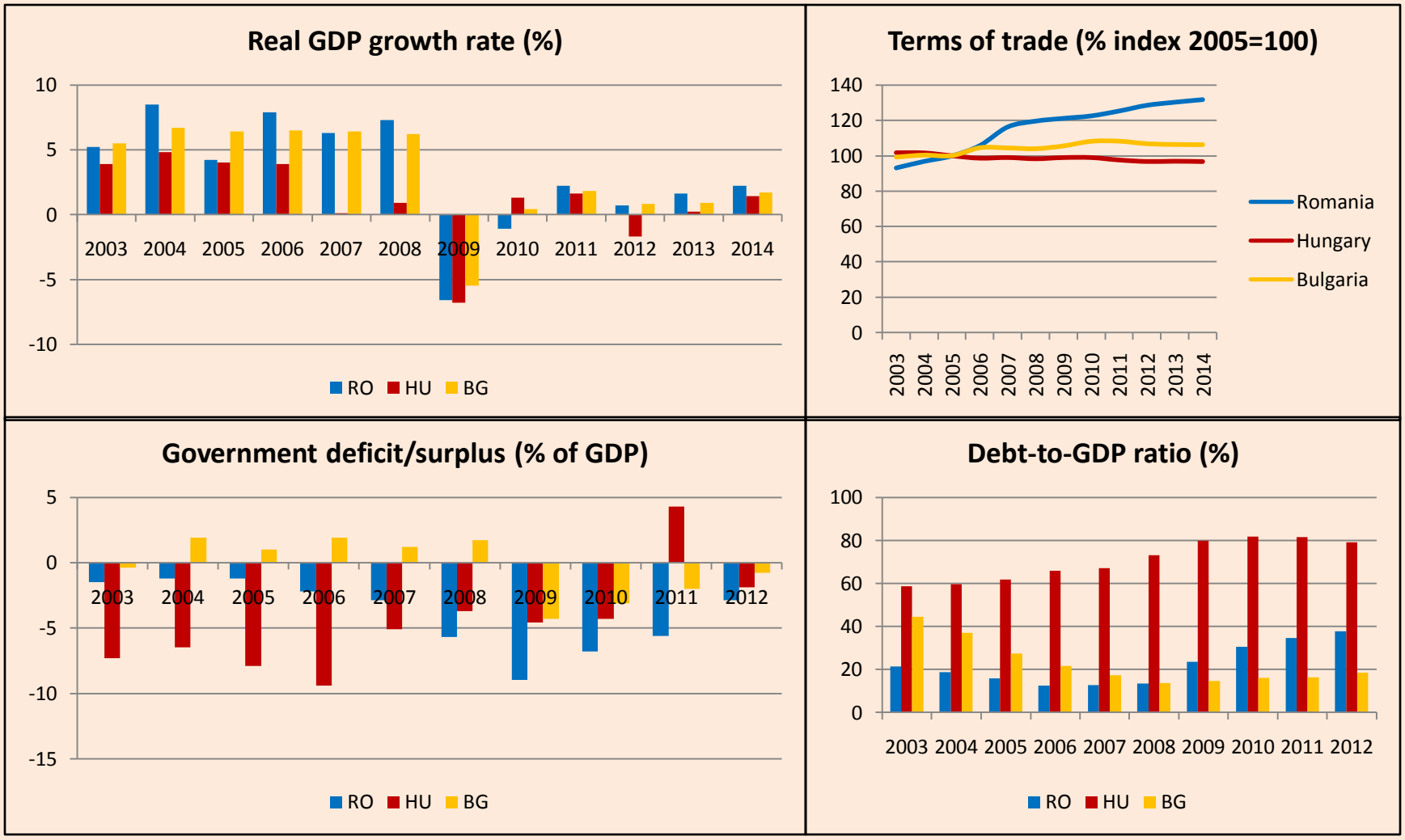
Table nr. 9 – Model generated probability of default for the 3 countries in Case 3 in the last year

	pd_RO	pd_HU	pd_BG
ian.12	10.30%	18.90%	14.68%
feb.12	10.77%	18.87%	14.63%
mar.12	10.60%	18.81%	14.51%
apr.12	10.65%	18.28%	14.52%
mai.12	10.89%	18.43%	14.98%
iun.12	11.20%	17.84%	14.65%
iul.12	10.92%	16.59%	14.72%
aug.12	10.80%	16.31%	14.74%
sep.12	10.99%	16.18%	14.25%
oct.12	11.03%	16.11%	13.22%
nov.12	11.04%	15.08%	13.15%
dec.12	10.62%	15.72%	13.49%
ian.13	10.87%	15.63%	12.84%

- to check if obtained results are consistent with the economic situation of each country I illustrate a comparison between a few economic indicators
- between the 3 countries analyzed Hungary is the riskiest one

INTERPRETATIONS (5)

Figure no.14 – Economic Indicators



CONCLUSIONS

- sovereign risk, measured through market CDS spreads, is not necessarily country specific
- CCA has some limitations: when low sovereign equity volatility is used as an input, model generated spread and volatility of default have a near zero value
- to counteract the implications of a low volatility and also to obtain risk indicators that follow the market CDS spreads as closely as possible, the volatility of a representative stock index can be used as a proxy for sovereign equity volatility; the results are significantly improved
- of the three analyzed countries Hungary is the riskiest with a 1-year horizon probability of default equal to 15. 72% at the end of 2012, while the pd for Romania is 10.62% and Bulgaria - 13.49%; this result is consistent with real GDP growth forecast for 2013 – Hungary: 0.2%, Romania: 1.6% and Bulgaria: 0.9%

- there are several ways to improve the estimated model:
  - instead of using historical index volatility, implied volatility from traded options could be used or a stochastic volatility model could be employed in order to estimate stock index volatility;
  - the willingness-to-pay could be taken into consideration;
- to further extend the model the links between sectors could be studied within a *systemic CCA* framework

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