DYNAMIC ECONOMETRIC MODELS
Vol. 11 – Nicolaus Copernicus University – Toruń – 2011

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Sovereign CDS Instruments in Central Europe – Linkages and Interdependence†

A b s t r a c t. In the article, linkages among sovereign CDS instruments in Central Europe are investigated. Special attention is paid to the change of causality patterns during the Hungarian and Greek crises. The results of the research reveal that the expectations do play a role in determining the prices of the contracts, as well as that there exist regional causality relationships between the instruments. The strength of causality between the volatilities of Polish – Hungarian and Czech-Hungarian CDS prices weakened during the Hungarian crisis, while the volatilities of the three time series reacted rapidly and strongly to the Greek one. This suggest that the European events should play more important role in determining the dynamics of the contracts than the problems of the country of the weakest fundamentals in the region.

K e y w o r d s: multivariate volatility, credit default swap, contagion, sunspot, Central Europe.

Introduction

Sovereign CDS contracts attracted special attention of the researchers starting from the outbreak of the recent financial crisis. Beforehand, most of the research concentrated on the corporate CDS contracts and analysed interrelations of the CDS spreads with other financial instruments. To name a few: Hull, Predescu and White (2004) analysed relationships between the CDS spreads, bond yields and credit rating announcements over the period 1998-2002. Benkert (2004) searched for the factors explaining the dynamics of the CDS premia, finding option-implied volatility especially significant in explaining their variability. Some studies concentrated on the interrelations between the premia of the corporate CDS contracts. Such an example can be the paper by Coudert and Gex (2008) in which the authors analyse possible contagion of the

† The work is supported by the Polish Ministry of Science and Higher Education through the Project NN 112372340. The author would like to thank the members of the project, especially Jacek Wallusch and Michał Adam for their help, cooperation and fruitful comments on the article, as well as the two anonymous referees for their useful and inspiring remarks.

crisis experienced by General Motors and Ford in May 2005 to the whole CDS market. Jorion and Zhang (2007) show how information of credit event of a given company is transferred among the other companies through the CDS market in USA over the period 2001–2004.

Most recently, more and more attention is paid to the interrelations between the sovereign CDS instruments. An example can be the work of Calice, Chen and Williams (2011) in which the authors analyse the interrelations between the CDS contract and bonds markets in the Eurozone. Alter and Schüler (2011) investigated interdependence of the sovereign and banks' CDS series of chosen European countries (France, Germany, Italy, Ireland, Netherlands, Portugal and Spain). Alfonso, Furceri and Gomes (2011) carried an event-study analysis to check the reaction of sovereign bond yields and CDS spreads to the rating agency announcements, finding among all that the reaction of the CDS spreads to the negative news increased after the Lehman Brothers' bankruptcy. The dataset used by the authors included EMU and non-EMU countries, among all Czech Republic, Hungary and Poland, and covers the period from January 1995 to October 2010.

The aim of this paper is to investigate possible linkages and interdependence among Central European sovereign CDS instruments of 5 year maturity during the hectic period of recent financial crisis. The author wants to verify whether the price of the sovereign CDS instruments is determined mainly by fundamentals or whether the premium is influenced by expectations (sunspots). The author first analyses volatilities of the CDS spreads to find any common patterns of their dynamics. Next, the non-causality test of Cheung and Ng (1996) is run to verify the possible moments of causality and to relate them to the crisis events. Eventually, to check the strength of causality, the author estimates the multivariate stochastic volatility model with Granger-causality of Yu and Meyer (2006). The results of the research show that the price of the instruments is indeed influenced by expectations (e.g. a significant reaction of volatilities to the Greek crisis was found). Regional linkages (measured by Granger-causality relations) do exist, but in the analysed period they played less important role (reaction of volatilities of Polish and Czech instruments to the Hungarian problems was not comparable to their reaction to the Greek crisis). The finding that the negative events influence significantly the price of the CDS is consistent with the previous finding, cited above.

1. CDS Instruments – an Overview

Credit Default Swap (in short: CDS) is an instrument that gives the holder right to sell a bond for its face value in the event of a default by the issuer (Hull, 2008). This credit derivative constitutes a form of insurance which protects the buyer of the CDS in the case of a loan default by particular company. The company is known as the reference entity and a default by the company is known as a credit event. The buyer of the CDS makes periodic payments to the seller until the end of life of the CDS or until a credit event occurs. The total amount paid per year as a percent of the notional principal to buy the protection is called the CDS spread (Hull, 2008).

Many different companies and countries are reference entities for the CDS contracts. Special kinds of CDS contracts are the sovereign ones, the underlying instruments of which are government bonds. Spreads of such CDS instruments can be also used as indicators of the credit-worthiness of a given country (Hull, 2008). Usually, each negative (and positive) piece of information about financial situation of a given country is reflected in the CDS spread. It is noticeable that negative information contributes to the growth of the CDS premia, while the positive one – to its lowering. The more liquid the market, the more perceptible are these movements. The sovereign debt market has attracted considerable attention since September 2008, while before the crisis trading concentrated on private sector instruments (Fontana, Scheicher, 2010).

2. CDS Instruments in Central Europe

Let us take a look at the Figure 1. It presents the dynamics of the CDS spreads of 5 year maturity quoted for Czech Republic, Hungary and Poland over the period March 2008 – March 2011. First of all, we can notice that the spreads for Hungary are the highest. Next, we can observe some similarities in the behaviour of all the three spreads. There was a significant jump in the middle of October 2008.

According to the Financial Stability Report (NBP, 2009) "the rise in CDS premium on the Polish government debt was largely connected with the global tendency to assess credit risk very prudently and the negative impact of the situation in the region on perception of investment risk in Poland". Moreover, the probability of default of the Polish government implied by the prices of CDS was much higher than other ratings suggested. The rating implied by the CDS prices was BBB, while Moody's assessment was A2 and S&P's and Fitch's: A-. On contrary, the rating for Hungary was lowered several times in 2008 and 2009. For example, on October 15th the rating for Hungary was changed by S&P from A2 to A2 with negative outlook. The rating was lowered again on November 17th, 2008 and on March 30th, 2009. The changes in ratings appeared rather seldom and were not as sharp as the dynamics of the CDS prices could suggest.

In the second half of 2009 the situation stabilised. Since the beginning of 2010 the CDS premia in the three countries decreased, falling to the lowest levels since September 2008. However, in May 2010 the rise in risk aversion connected with Greek insolvency affected also the Central European CDS market. Thus, we could observe the rise in the CDS premia to the level recorded in the second quarter of 2009. On May 9th, the European Stabilisation Mechanism has been announced and shortly afterwards the risk assessment of Central European Bonds improved (NBP, 2010). However, in June it rose again. The highest growth was observed in Hungary. This growth of the CDS premium in Hungary can be also explained by the worsening economic situation of the country. Already on June 3rd, a leader of the ruling Fidesz party said that the country's finances were in much worse condition than previously expected. Also the vice chairman of Fidesz party stated that there was only a slim chance to avoid Greek scenario (according to: www.napi.hu). In consequence, the five-year Credit Default Swaps on Hungary rose by 58 basis points to 320 basis points, which is reflected in Figure 1. On June 12th, Moody changed its rating for Hungary from BAA1 to BAA3 with negative outlook. Again, on July 17th the EU and IMF suspended a review of Hungary's funding program (which had been set up in 2008 to save the country from financial problems) and said that the country must have taken action to meet targets for cutting its budget deficits. The suspension meant that Hungary would not have access to the remaining funds in its loan package. This event could have contributed to the increase of the CDS price in the second half of July. Eventually, the pick of the CDS price in November can be explained by the reforms of the pension system announced by the Hungarian government.

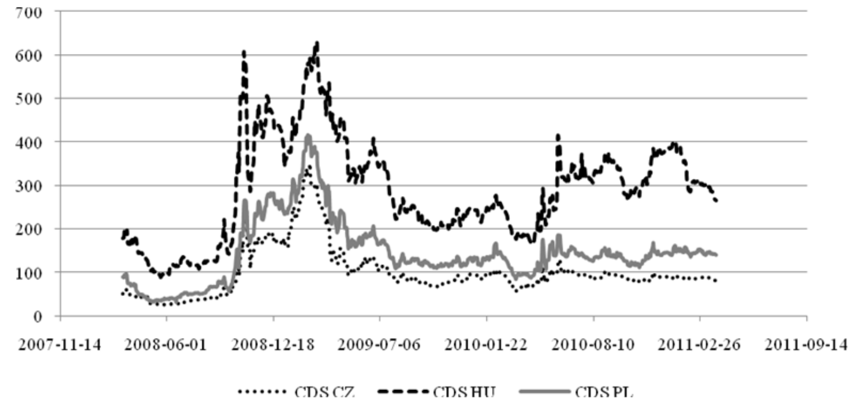

Figure 1. Corporate 5-year CDS spreads in bps for Czech Republic, Poland and Hungary

2.1. Data Description

As already said, the analysed sample covered the period from March 2008 to March 2011 and consisted of 796 observations. The data was provided by Bloomberg. Obviously, the spreads were not stationary, so we run all our tests on the changes of the prices ($P_t - P_{t-t}$). We did not take the logarithms of the increments to avoid problems with interpretation of such transformed series (the prices of the CDS contracts are expressed in basis points).

Table 1 presents the descriptive statistics of the increments of the daily changes of the prices for Czech Republic, Hungary and Poland. As expected, the highest deviation is observed in case of the Hungarian instruments, while the lowest – in case of the Czech ones.

Table 1. Descriptive statistics of the price changes of the Central European CDS

Variable	Min Value	Mean Value	Max Value	Std. Deviation
dCDS_CZ	-57.503	0.038	54.998	6.693
dCDS_HU	-83.332	0.156	98.033	14.294
dCDS_PL	-46.654	0.064	47.333	8.154
date	10.03.2008	-	28.03.2011	-

3. Non-causality Analysis – Tests Based upon the GARCH-type Models

In order to test whether expectations play a role in CDS pricing, we tested for the volatility interactions in the CDS prices. Detecting volatility spillovers in the data is the sign of contagion. The type of contagion which is expectation-driven is called sunspot – see e.g. (Keister, 2006). The occurrence of the sunspot is connected with the period of volatility growth – thus we first estimate univariate volatility models to test for possible moments of contagion.

3.1. Volatility Dynamics of the CDS Prices – a Univariate GARCH Analysis

To begin with, we first fit univariate GARCH models to the data and searched for the moments of higher volatility. As stated before, the moments of abnormal volatility growth can indicate the sunspot event. Thus, we fit the GARCH models to each of the series. Since in each case the sum of the parameters α and β in estimated GARCH(1,1) models exceeded 1, we decided for IGARCH models with Student distribution. In case of Hungarian and Polish CDS it was also necessary to account for ARMA effect in the conditional mean equation, as well as to assume Student distribution. Each of the fitted model was successfully tested against autocorrelation in mean (Box-Pierce test) as well as ARCH effect (Engle test) and stability of the parameters (Nyblom test). All computations presented in this paragraph were performed using OxMetrics 6 with package G@RCH. Tables 2– 4 present the estimated parameters, while the Figures 2 to 4 the estimates of volatilities of each time series.

Table 2. Estimates of ARMA(0,0)-IGARCH model for Czech CDS

Coefficient	Estimated value	Std. Error	p-value
ϖ	0.248	0.181	-
α	0.175	0.043	0.000
β	0.825	-	-

Note: All parameters appeared to be stable, according to the Nyblom stability test.

Table 3. Estimates of ARMA(1,0)-IGARCH(1,1) model for Polish CDS

Coefficient	Estimated value	Std. Error	p-value
AR(1)	0.136	0.040	0.001
ϖ	0.344	0.195	-
α	0.188	0.029	0.000
β	0.812	-	-
Degrees of freedom	4.867	0.632	-

Note: All parameters appeared to be stable, according to the Nyblom stability test.

Table 4. Estimates of ARMA(0,1)-IGARCH(1,1) model for Hungarian CDS

Coefficient	Estimated value	Std. Error	p-value
MA(1)	0.163	0.036	0.000
ϖ	3.616	1.937	-
α	0.280	0.088	0.002
β	0.720	-	-
Degrees of freedom	3.881	0.460	-

Note: All parameters appeared to be stable, according to the Nyblom stability test.

We plot the obtained estimates of conditional variances in Figures 2–4. We can observe that the moments of volatility growth in the three countries overlap. The first one started in September 2008 and was most probably connected with the worldwide financial crisis. The second one started in May 2010 and may have two causes. Either it was the reaction for the Greek crisis or the echo of the turmoil in Hungary. It is worth noting that the second pick of volatility was much smaller in the case of Czech CDS price than the one observed for Polish and Hungarian CDS price. What is important, during the "second turmoil" we observe the picks in volatility on May 11th in the case of the three time series. However, in the case of Hungary, this pick is relatively small as compared to the one observed on June 7th, which may have been caused by the statements of the leaders of the ruling Fidesz party about the very poor economic situation of the country. The third pick appeared on July 21st and was most probably the consequence of the suspension of the funding program for Hungary.

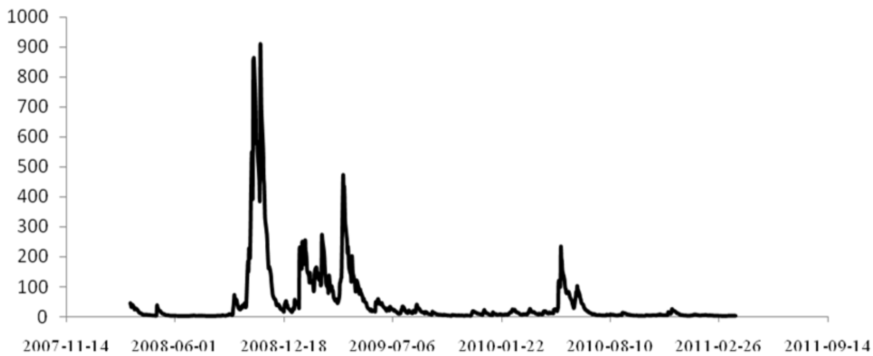

Figure 2. Estimates of conditional variance for Czech CDS

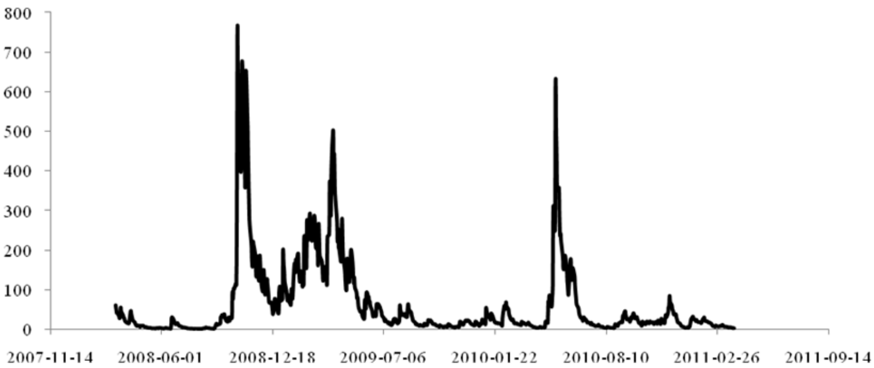

Figure 3. Estimates of conditional variance for Polish CDS

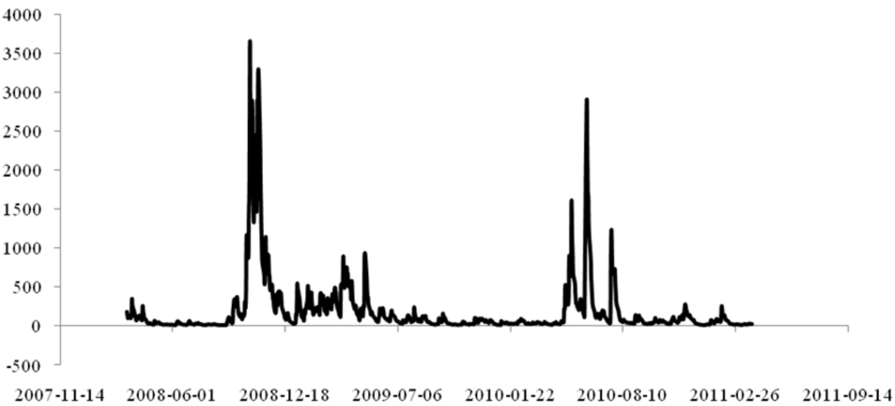

Figure 4. Estimates of conditional variance of Hungarian CDS

3.2. Non-causality Test of Cheung and Ng

Based upon the obtained estimates of the volatility of the CDS contracts, we computed the statistics of the non-causality test of Cheung and Ng (1996) – see the Appendix for details. The statistics are used to test the null hypothesis of no causality in variance. Table 5 presents the results. In all the cases the null of no causality was rejected. However, the highest value took the statistics obtained for Hungarian and Polish CDS variances.

Table 5. Statistics of the non-causality in variance test of Cheung and Ng

j=0,k=	CZ→PL	PL→CZ	HU→PL	PL→HU	HU→CZ	CZ-→HU	χ^2
1	43.045	43.554	60.905	60.768	23.392	23.392	5.991
2	43.563	44.105	61.311	61.116	23.410	23.495	7.815
3	44.436	44.328	61.312	61.119	23.644	24.153	9.488

Additionally, taking advantage of the statistics constructed for small samples, we computed the test for the moving window of 120 observations. Let us assume that the relationship implied by the test is valid for the period of 120 days, ending on the day of the window end. We present the results in Figures 5–10. The points of the second coordinate equal to 1 denote the moments in which we rejected the hypothesis of non-causality at lag 1. The pictures reveal some interesting patterns. The causality relationships are bilateral (there occurs the "feedback" according to the Cheung and Ng terminology). Yet, in the case of Poland and Czech Republic, the period of constant causality in variance begins in summer 2009, while in the case of Poland and Hungary – it ends in summer 2010. This means that there was a year period of feedback Poland-Hungary, Poland-Czech Republic, which ended in case of the Poland-Hungary relationships in the moment of the turbulence in Hungary. What is interesting, the Hungarian crisis did not affect to such extend the causality patterns with Czech Republic. Although there appear moments of non-causality, as for example in November 2010, in general the null is rejected. However, the fact that in November 2010 the causality linkages weakened suggests that the pension crisis in Hungary did not affect the way the market participants value the risk of investment in Czech Republic.

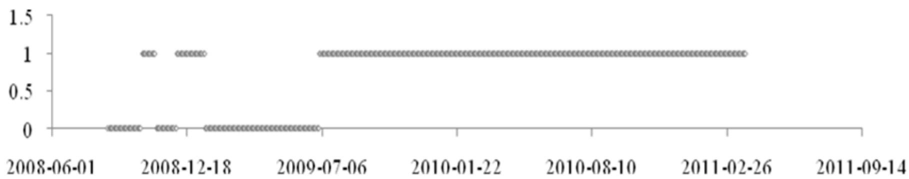

Figure 5. Periods of causality in variance: Poland - Czech Republic

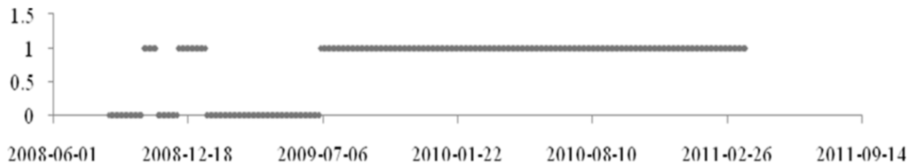

Figure 6. Periods of causality in variance: Czech Republic - Poland

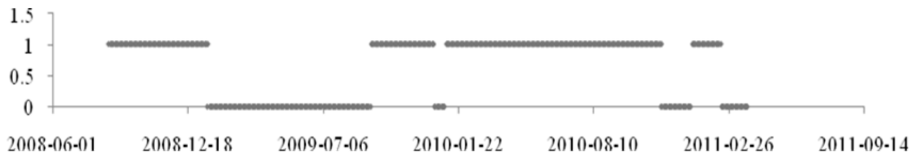

Figure 7. Periods of causality in variance: Czech Republic – Hungary

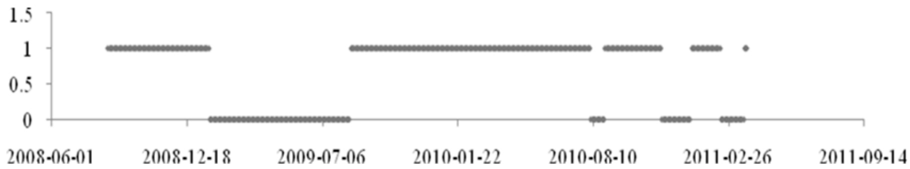

Figure 8. Periods of causality in variance: Hungary - Czech Republic

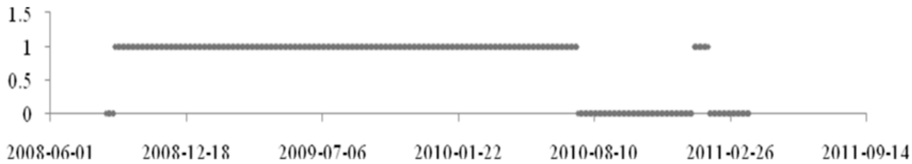

Figure 9. Periods of causality in variance: Poland - Hungary

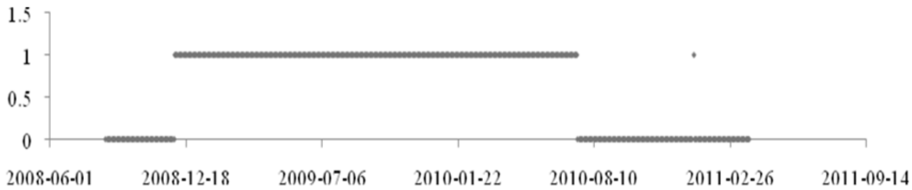

Figure 10. Periods of causality in variance: Hungary-Poland

The results of the test suggest that the two moments of turbulence denoted by volatility growth were of different nature. While in the first phase of the crisis we could observe significant interrelations between volatility of Polish and Hungarian CDS instruments, as well as between Czech and Hungarian ones, suggesting that the crisis may have been regional or that at least it was considered so by the investors, the situation changed during the second volatility pick. Although in spring 2010 the null of non-causality was rejected, in summer and autumn – when the crisis in Hungary intensified – the causality relations weakened significantly. This can suggest that the contagion did occur, but its source was outside the Central Europe. Most probably, as suggested in the NBP's Financial Stability Reports, there was a global growth of risk perception as a reaction to the Greek problems. However, the Hungarian crisis did not infect the rest of the analysed Central European countries. It seems that either the investors did not perceive the Hungarian problems as contagious or that the CDS prices did not reflect the market reality. The latter problem could occur if the market was not liquid. However, as presented in Figure 11 the instruments are indeed traded intensively, and the most liquid ones are the Hungarian CDS contracts.

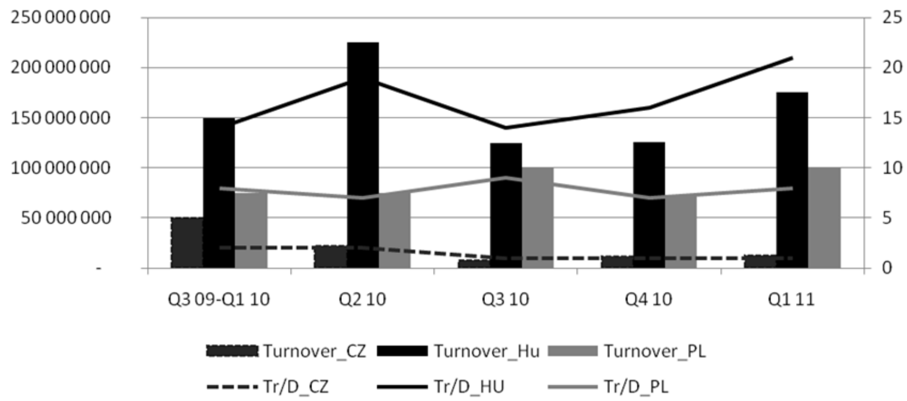

Figure 11. Turnovers on the CDS market - quarterly data

4. Analysis of Granger Causality in Variance – a Multivariate Stochastic Volatility Model

The test of Cheung and Ng allows us to test the direction of causality, not the strength of it. Thus, we also estimated a model of Yu and Meyer (2006) – a Multivariate Stochastic Volatility model with Granger causality (see the Appendix for details), allowing not only for detecting the causality patterns (in Granger sense), but also the strength of them.

First, we estimated a VAR equation for the Polish and Hungarian CDS prices in order to account for any linear dependencies in the data. The results are presented in Tables 6–7. Order of equation was chosen using Schwarz information criterion. In case of the Hungarian CDS price, it appears that it was influenced by the past values of this instrument price (lagged value of Polish CDS price is insignificant). Similarly, the price of Polish CDS is also influenced by the past value of Hungarian CDS price.

Table 6. VAR equation for Hungarian CDS (Polish and Hungarian CDS in the system)

Parameter name	Estimate	Std. Error	P-value
CDShu(-1)	0.261	0.054	0
CDSpl(-1)	-0.014	0.094	0.878
Const.	0.079	0.482	0.870

Table 7. VAR equation for Polish CDS (Polish and Hungarian CDS in the system)

Parameter name	Estimate	Std. Error	P-value
CDSpl(-1)	-0.0230	0.054	0.864
CDShu(-1)	0.154	0.031	0
Const.	0.047	0.276	0.864

The volatility model was estimated for the residuals from the VAR system, using the free software WinBUGS (version 1.4). Since the program uses the

Bayesian approach to the estimation, we assume that all the parameters are stochastic variables. To give the readers an approximation of the point estimates, we present the means and medians of the distributions, as well as the standard deviations. The results are presented in Table 8. Moreover, in the case of the parameters ϕ_{12} and ϕ_{21}, we present the obtained density functions (Figure 11 and 12).

Table 8. Results of the estimation of GC-MSV model for Hungarian (1) and Polish (2) CDS prices

Variable name	Mean	Standard deviation	MC error	2.5% percentile	Median	97.5% percentile
μ_1	4.063	0.368	0.025	3.340	4.038	4.858
μ_2	3.100	0.395	0.027	2.332	3.077	3.964
ϕ_1	0.697	0.061	0.004	0.566	0.702	0.803
ϕ_2	0.877	0.043	0.003	0.785	0.879	0.954
ϕ_{12}	0.098	0.044	0.003	0.021	0.096	0.192
ϕ_{21}	0.247	0.058	0.004	0.146	0.241	0.373
σ_{η_1}	0.674	0.061	0.004	0.554	0.674	0.796
σ_{η_2}	0.431	0.053	0.005	0.330	0.429	0.537
ρ_{ε}	0.752	0.019	0.001	0.714	0.753	0.789

Thus, we conclude that there exist causality between the volatility of Polish and Hungarian CDS contracts. Based upon the obtained distribution we can conclude that the volatility of Polish CDS Granger-causes the volatility of Hungarian CDS. Since the result was obtained for the whole sample, we can expect that the direction of causality is constant over time.

Table 9. VAR equation for Polish CDS (Polish and Czech CDS in the system)

Parameter name	Estimate	Std. Error	P-value
Const.	0.054	0.278	0.847
CDSpl(-1)	0.044	0.047	0.356
CDSpl(-2)	-0.050	0.048	0.296
CDScz(-1)	0.241	0.057	0
CDScz(-2)	0.064	0.056	0.259

Table 10. VAR equation for Czech CDS (Polish and Czech CDS in the system)

Parameter name	Estimate	Std. Error	P-value
Const.	0.023	0.227	0.919
CDSpl(-1)	0.314	0.039	0
CDSpl(-2)	0.106	0.039	0.006
CDScz(-1)	-0.147	0.047	0.002
CDScz(-2)	-0.184	0.046	0

We followed the same procedure in order to verify the interactions between Polish and Czech, as well as Czech and Hungarian CDS prices. The results are presented in Tables 9–11.

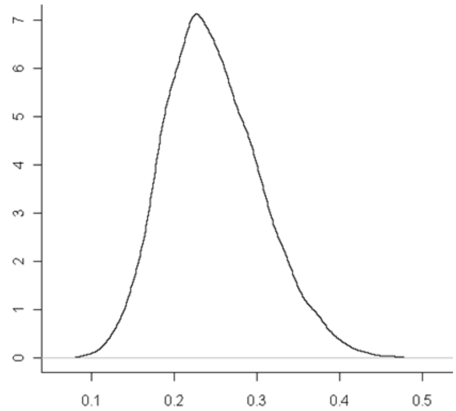

Figure 12. Density of the parameter ϕ_{12} (causality from Poland to Hungary)

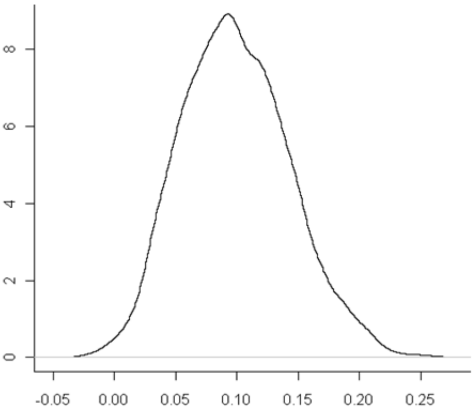

Figure 13. Density of the parameter ϕ_{21} (causality from Hungary to Poland)

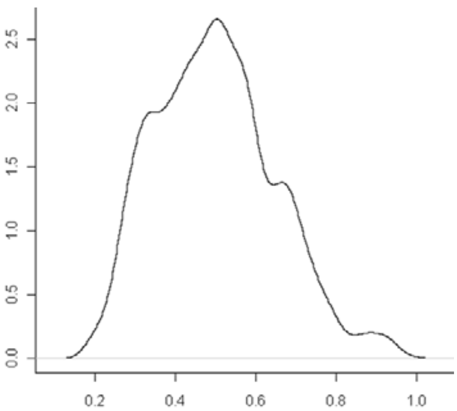

Figure 14. Density of the parameter ϕ_{21} (causality from Poland to Czech Republic)

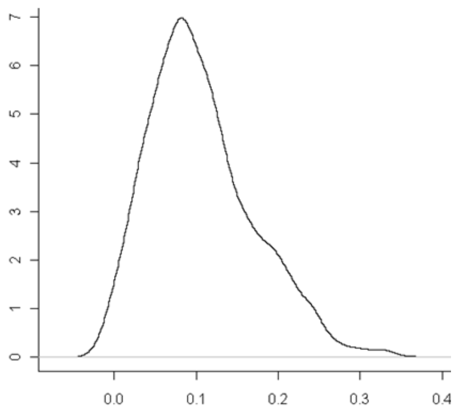

Figure 15. Density of the parameter ϕ_{12} (causality from Czech Republic to Poland)

In case of the interactions between Polish and Czech CDS prices we observe that Polish CDS price are influenced by the prices of Czech CDS from the previous day, while the prices of Czech CDS are influenced by the prices of both Polish and Hungarian CDS from one and two days before. In case of the second moment dependency, it is again Polish CDS volatility that influences the volatility of the Czech CDS (parameter ϕ_{21}). The second "causality parameter" – ϕ_{12} – takes smaller value and its standard deviation amounts to 60% of its mean value. Thus, we conclude that the investors do not assess the risk of investment in Poland based upon the worsening situation of other Central European countries, as before. Moreover, it is the volatility of Polish CDS that affects the volatility of the other Central European ones the most. Figures 14 and 15 present the obtained densities of the causality parameters. Eventually, we investigated the causality patterns in case of Hungarian and Czech CDS prices. The results are displayed in Tables 12–14.

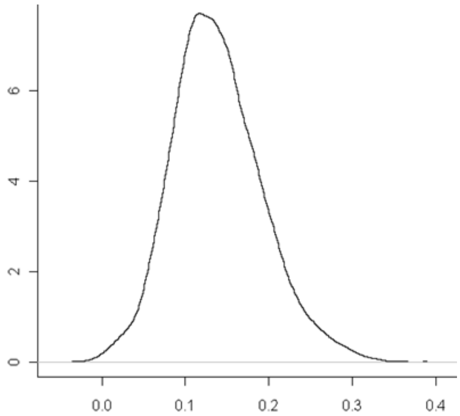

Figure 16. Density of the parameter ϕ_{21} (causality from Czech Republic to Hungary)

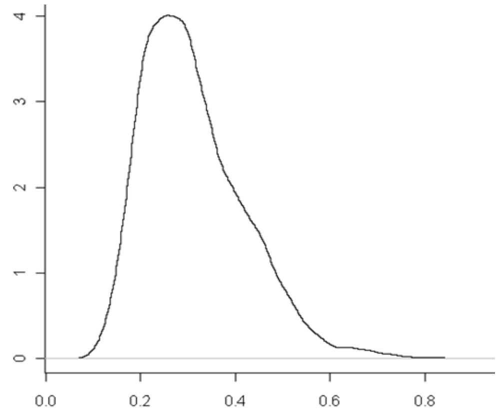

Figure 17. Density of the parameter ϕ_{12} (causality from Hungary to Czech Republic)

Table 11. Results of the estimation of GC-MSV model for Polish (1) and Czech (2) CDS prices

Variable name	Mean	Standard deviation	MC error	2.5% percentile	Median	97.5% percentile
μ_1	3.150	0.365	0.027	2.474	3.150	3.942
μ_2	2.196	0.421	0.031	1.419	2.190	3.097
ϕ_1	0.844	0.080	0.006	0.666	0.856	0.969
ϕ_2	0.558	0.125	0.010	0.283	0.562	0.767
ϕ_{12}	0.106	0.065	0.005	0.003	0.096	0.250
ϕ_{21}	0.499	0.151	0.012	0.251	0.493	0.828
σ_{η_1}	0.422	0.073	0.006	0.307	0.412	0.590
σ_{η_2}	0.574	0.095	0.007	0.388	0.572	0.766
ρ_ε	0.622	0.026	0.001	0.568	0.622	0.669

Based upon the estimated VAR model we can conclude that the price of Czech CDS depended on the past values of itself and Hungarian CDS price. In case of the causality in the second moments, we observe small values of the "causality coefficients". Although the value of ϕ_{12} is more than two times higher than the one of ϕ_{21}, in both cases the standard deviation of the obtained coefficients exceed 35% of their means. Thus, we can expect bivariate causality on quite low level, a little higher in case of Hungarian influence on the volatility of Czech CDS. The results are presented in Figure 16 and 17.

Table 12. VAR equation for Czech CDS (Czech and Hungarian CDS in the system)

Parameter name	Estimate	Std. Error	P-value
Const.	0.025	0.228	0.914
CDScz(-1)	-0.095	0.043	0.027
CDShu(-1)	0.161	0.021	0

Table 13. VAR equation for Hungarian CDS (Czech and Hungarian CDS in the system)

Parameter name	Estimate	Std. Error	P-value
Const.	0.078	0.481	0.871
CDScz(-1)	0.143	0.091	0.114
CDShu(-1)	0.213	0.043	0

Table 14. Results of the estimation of GC-MSV model for Czech (1) and Hungarian (2) CDS prices

Variable name	Mean	Standard deviation	MC error	2.5% percentile	Median	97.5% percentile
μ_1	2.053	0.394	0.026	1.284	2.051	2.878
μ_2	4.040	0.334	0.022	3.373	4.035	4.706
ϕ_1	0.700	0.091	0.008	0.501	0.714	0.839
ϕ_2	0.772	0.068	0.006	0.621	0.777	0.897
ϕ_{12}	0.312	0.109	0.010	0.153	0.293	0.562
ϕ_{21}	0.138	0.055	0.004	0.041	0.134	0.260
σ_{η_1}	0.719	0.096	0.009	0.562	0.704	0.918
σ_{η_2}	0.669	0.089	0.008	0.465	0.670	0.841
ρ_{ε}	0.588	0.028	0.001	0.532	0.588	0.641

Conclusions

The aim of the research was to verify whether there appear significant interactions between volatilities of the Central European CDS prices, suggesting that their price can be influenced not only by fundamentals, but also by expectations (sunspot event). To verify this, first univariate volatility models were estimated to check for the periods of volatility growth. Next, the Cheung-Ng test for non-causality in variance was run, using the rolling-over approach and the test version suitable for the small samples. The author was interested in revealing the possible sources of the volatility growth in case of the CDS prices in the three countries, in spring 2010. Usually the situation of volatility growth is associated with the occurrence of sunspot event. There may have been two sources of such contagion – either the global growth of risk aversion due to the Greek crisis, or the local turmoil caused by the worsening economic situation of Hungary. It appeared, however, that the moments in which the null hypothesis of non-causality in the pairs including Hungary was not rejected, overlapped with the moment of Hungarian crisis in 2010. It was also observed that the periods of higher volatility in Hungary did not have equivalents in Polish and Czech CDS volatility. Such situation can indicate that the investors do not expect the crisis outbreak in Poland or Czech Republic when it happens in Hungary and they do not assess the risk of investment in the whole Central Europe based upon the situation in the country of weaker fundamentals.

Eventually, yet anoher test for causality in variance was performed, through estimating bivariate stochastic volatility models with Granger causality for each pair of instruments. The results are clear: there is a strong causality from Polish CDS volatility to the volatility of the rest CDS prices.

The increase in conditional volatilities of the instruments in spring 2010 can suggest that contagion did occur. However, according to the presented results, the source of it was outside the Central Europe. If there was a reaction to the turmoil in Hungary, it was not reflected in the volatilities of Polish and Czech CDS prices. Thus, the reaction of the CDS prices of Poland and Czech republic to the problems in Hungary was not noticeable. However, the fact that the events of causality appeared during the problems in Greece can suggest that expectations do play a role in CDS pricing. Since the Central Europe is not critically linked via fundamentals with the Southern one, the contagion which occurred in May 2010 must be so called "expectations-driven".

What is more, the results of the research show also that there exist causality linkages in the second moments of the CDS prices processes. Significant reactions of volatilities of Czech and Hungarian CDS prices to the changes of the volatility of Polish CDS price were found. The linkages are in fact bilateral, but the causality from Poland is much stronger. On the other hand, the turnover on the Hungarian CDS market was the highest in the analysed period. The explanation of the result can be the following – the sovereign CDS instruments are bought mainly for speculation. In the period over study Hungary was the most risky country from the region, and investments in Hungarian swaps could allow for the highest earnings. Thus, the investors were interested in trading these particular instruments. However, from the analysed markets, the Polish one is the biggest and if an investor wants to sell his assets in a Central European market as quickly as possible, the easiest way is to trade them on the Polish stock exchange. This may explain the fact that – although the turnover on the Hungarian CDS market was the highest – the strongest causality in variance occurred from the Polish one. This conclusion could explain why the volatility of Polish and Czech CDS prices did not react to the Hungarian problems.

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Appendix

Non-Causality test of Cheung and Ng

Let us consider two stationary and ergodic time series processes: X_t and Y_t, as well as two information sets defined by: $I_t = \{X_{t-1}, j \geq 0\}$ and $J_t = \{X_{t-j}, Y_{t-j}, j \geq 0\}$. Y_t is said to cause X_{t+1} in variance if

$$E[(X_{t+1}-\mu_{x,t+1})^2 \mid I_t] \neq E[(X_{t+1}-\mu_{x,t+1})^2 \mid J_t],$$

where $\mu_{x,t+1}$ is the conditional mean of X_{t+1} (conditioned on I_t). Feedback in variance occurs when *X* causes *Y*, and *Y* causes *X*. Let us also suppose that:

$$X_t = \mu_{x,t} + h_{x,t}^{1/2}\varepsilon_t,$$
$$Y_t = \mu_{y,t} + h_{y,t}^{1/2}\xi_t.$$

In the model above, $\mu_{z,t}$ denotes conditional mean, $h_{z,t}$ conditional variance, while ε_t and ξ_t are white noise processes with null mean. Let U_t and V_t denote squares of standardised residuals:

$$U_t = \frac{(X_t-\mu_{x,t})^2}{h_{x,t}} = \varepsilon_t^2, \qquad V_t = \frac{(Y_t-\mu_{y,t})^2}{h_{y,t}} = \xi_t^2.$$

Let $r_{U,V}(k)$ denote cross-correlation between *U* and *V*, for the *k*-th lag:

$$r_{U,V}(k) = \frac{c_{U,V}(k)}{\sqrt{(c_{U,U}(0)c_{V,V}(0))}},$$

where $c_{U,V}(k)$ denotes covariance between *U* and *V* at lag *k*. Since the processes *U* and *V* are independent:

$$\begin{matrix}\sqrt{T}r_{U,V}(k)\\ \sqrt{T}r_{U,V}(j)\end{matrix} \to N\left(\begin{bmatrix}0\\0\end{bmatrix},\begin{bmatrix}1 & 0\\0 & 1\end{bmatrix}\right), k \neq j.$$

Cheung and Ng (1996) proposed the following test to verify the causality in variance. First, we construct the following statistics:

$$S = T\sum_{i=j}^{k}\hat{r}_{U,V}^2(i),$$

which is distributed according to χ^2 distribution with (*k*-*j*+1) degrees of freedom. If the sample is small, the following, corrected version of the statistics is applied:

$$S = T\varpi_i\sum_{i=j}^{k}\hat{r}_{U,V}^2(i),$$

where $\omega_i = \dfrac{T+2}{T-|i|}$.

Multivariate Stochastic Volatility Model with Granger Causality of Yu and Meyer

The model has the following form:

$$\mathbf{y}_t = \mathbf{\Omega}_t \boldsymbol{\varepsilon}_t,\ \boldsymbol{\varepsilon}_t \sim iid(\mathbf{0}, \mathbf{\Sigma}_\varepsilon),$$

$$\mathbf{h}_{t+1} = \boldsymbol{\mu} + \mathbf{\Phi}(\mathbf{h}_t - \boldsymbol{\mu}) + \boldsymbol{\eta}_{t,}\ \boldsymbol{\eta}_t \sim iid(0, diag(\sigma^2_{\eta_1}, \sigma^2_{\eta_2})),$$

where:

$\mathbf{y} = (y_1, y_2)'$ denotes the mean-adjusted time series of data,

$\mathbf{\Omega}_t$ is a diagonal matrix ($\mathbf{\Omega}_t = diag(\exp(\frac{h_t}{2}))$,

$$\mathbf{\Sigma}_t = \begin{bmatrix} 1 & \rho_\varepsilon \\ \rho_\varepsilon & 1 \end{bmatrix}, \qquad \mathbf{\Phi} = \begin{bmatrix} \phi_{11} & \phi_{12} \\ \phi_{21} & \phi_{22} \end{bmatrix}.$$

Naturally, $\boldsymbol{\mu} = (\mu_1, \mu_2)', \mathbf{h}_t = (h_{1,t}, h_{2,t})', \boldsymbol{\varepsilon}_t = (\varepsilon_{1,t}, \varepsilon_{2,t})', \boldsymbol{\eta}_t = (\eta_{1,t}, \eta_{2,t})'$.

In the model it is assumed that the (mean-adjusted) returns and volatilities are cross-dependent, as well as that the volatility of the first asset can be Granger-caused by the volatility of the second one, and that the volatility of the second asset can be caused by the volatility of the first one. In order to investigate the direction of volatility spillovers we estimate the model and check the estimates of the parameters ϕ_{12} and ϕ_{21}.

Zależności i powiązania między instrumentami CDS na dług rządowy w gospodarkach Europy Środkowej

Z a r y s t r e ś c i. Artykuł przedstawia badanie współzależności między procesami cen instrumentów CDS (*credit default swap*) w Europie Środkowej. Autorka analizuje zależności między zmiennościami cen instrumentów w okresie kryzysowym starając się znaleźć odpowiedź na pytanie, czy ich cena determinowana jest w znacznym stopniu przez zależności regionalne i oczekiwania inwestorów (zjawisko zarażania sterowane oczekiwaniami, ang. *sunspot*). Wyniki przeprowadzonego badania sugerują, że ceny instrumentów CDS są w znacznym stopniu sterowane oczekiwaniami (gwałtowna reakcja na kryzys grecki), jak również że zależności regionalne – mimo że istnieją – mają mniejszy wpływ na cenę kontraktów, niż wydarzenia ogólnoeuropejskie.

S ł o w a k l u c z o w e: wielowymiarowe modele zmienności, CDS, Europa Środkowa, przeniesienie zmienności, *sunspot*.