JEL Classification: C32, C58, G01, G15
Keywords: sovereign CDS, government bonds, multivariate stochastic volatility, sunspot

The Dynamics of Sovereign Credit Default Swaps and the Evolution of the Financial Crisis in Selected Central European Economies*

Agata KLIBER—Poznan University of Economics (agata.kliber@ue.poznan.pl)

Abstract
In this paper, we analyze the dynamics of selected sovereign Central European credit default swap (hereinafter referred to as "sovereign CDS" or "sCDS") prices and investigate regional and European interdependencies among the economies under examination during the period 2008–2011. We focus our attention on the CDS market in Poland, the Czech Republic and Hungary, which are markets that researchers usually put into one "basket". The aim of our research is to verify to what extent the growth of the CDS premia in these countries during the period under study could be explained by the Hungarian and Greek crises. We apply stochastic volatility models with dynamic conditional correlation, including proxies for the Greek and Hungarian crises, in variance and correlation equations. On the basis of the obtained results, we conclude that regional dependencies between the Polish and Hungarian CDS prices are the strongest among all the analyzed pairs of countries. Both the Hungarian and Greek crises caused a rise in volatility in Central European countries. However, the shocks coming from the Greek market contributed to correlation growth between the Polish and Hungarian markets and, to a lesser extent, to the correlation of the Hungarian and Czech markets.

1. Introduction

The aim of the research was to investigate the dynamics of the Central European sovereign credit default swap (hereinafter referred to as "sCDS" or "sovereign CDS") price processes and to verify whether or not the prices of instruments are vulnerable to shifts in expectations, or in other words, whether sunspots play a role in determining the dynamics of these contracts. Additionally, we wanted to explore the causes of the enormous growth of premia in 2010, which in the case of Poland and the Czech Republic could not have been attributed to changes of fundamentals.

Sovereign CDS contracts attracted special attention of researchers from the outbreak of the recent financial crisis. However, most research is concentrated on the Eurozone (e.g. Calice et al., 2013a; Alter and Schüler, 2012) or on the Mediterranean region (e.g. Atrissi and Mezher, 2010; Aizenman et al., 2013), treating

* This study was supported by the Polish Ministry of Science and Higher Education through the project NN 112 372340 Non-fundamental shocks versus volatility of the exchange rate and the CDS market in selected Central European economies. The author is indebted to Dr. Jacek Wallusch and Michał Adam for their remarks on the early version of this paper, as well as Prof. Eric Girardin for his helpful comments and inspiration. I would like to thank the participants of the Forecasting Financial Markets (Hannover, 2013) and Macromodels (Warsaw, 2013) conferences for their discussion of this study. I am especially indebted to Prof. Małgorzata Doman for her professional advice. Finally, I am very grateful for the insightful and beneficial comments received from two anonymous reviewers, which allowed me to significantly improve the research and to see its results from a different perspective. Any and all mistakes are mine.

Central Europe marginally or neglecting it—see, for example, Gentile and Giordano (2012) as well as Broto and Peres-Quiros (2013).

Afonso et al. (2012) carried out an event-study analysis to check the reaction of sovereign bond yields and CDS spreads to the announcements of rating agencies, first finding that the reaction of the CDS spreads to negative news increased after the bankruptcy of Lehman Brothers. The dataset used by the authors included EMU and non-EMU countries, including the Czech Republic, Hungary and Poland, and covered the period from January 1995 to October 2010.

Aizenman et al. (2013) concentrated especially on the Mediterranean economies and Ireland (the so-called PIIGS countries: Portugal, Ireland, Italy, Greece and Spain) and verified whether or not their CDS contracts were mispriced in relation to their fundamentals measured, among others things, via the so-called fiscal space (government debt/tax and fiscal deficit/tax revenue). The group of Central European countries appeared in the research as a control group in the "basket" of non-PIIGS European countries. The authors found that, among other things, during the financial crisis the market overreacted and that the realized CDS prices were twice as high as those predicted by the model (compared to the pre-crisis period).

Chobanov et al. (2010) is one of the very few papers that concentrates on the sCDS market of the so-called new member states of the European Union rather than on that of developed economies. The authors studied links between liquidity and fiscal risk (the former measured by short-term money market rates, and the latter by CDS) during the financial crisis. The results are discussed with respect to different monetary regimes applied by the countries—inflation targeting (Poland, the Czech Republic, Hungary and Romania) and currency boards (Bulgaria, Estonia and Lithuania)—and are analyzed in different periods: before and during the crisis. The authors once again confirm that the crisis changed the risk perception of the economies and deepened the differences between the two analyzed group of countries (e.g., during the crisis higher fiscal risk led to a further rise of liquidity risk in the fixed-exchange economies, which was not the case in the inflation targeting economies).

Calice et al. (2013b) analyzed the term premium for a group of European countries (including those in Central Europe) and studied its short-term dynamics in high- and low-volatility regimes. The authors find that the factors that particularly influence these dynamics include CDS market liquidity, local stock returns and overall risk aversion. In periods of high volatility, the response of the CDS premium to shocks to the aforementioned variables is much stronger than during calm periods.

Kocsis (2013) analyzed different segments of financial markets, namely sCDS, stock indices, foreign exchange rates, EMBI (Emerging Markets Bond Index) Global spreads for foreign exchange bonds and ten-year yields of domestic bonds in order to separate global, regional and idiosyncratic components of the financial market indicators. The results confirm the importance of global and regional factors in CDS dynamics. The author illustrated the method taking into account the Hungarian case. He shows that in the case of the Hungarian CDS, it is the global factor through which Hungary and peripheral countries (also Poland) are correlated, while regional factors were weak channels of co-movement.

Similar results were obtained by Adam (2013), who studied the determinants of the dynamics of sovereign CDS in a wide range of countries, including Central

Europe. He confirms the existence of strong commonality among global credit spreads, and the importance of intraregional spillovers. He finds that volatility spillovers are significantly time-varying and that contagion from distressed countries diminishes over time.

Claeys and Vašíček (2012) also investigated interrelationships among sovereign markets, but rather concentrated on sovereign bond yields of European Union countries. The authors found out that volatility spillovers have increased substantially since 2007. Moreover, the Central and Eastern European markets proved to be linked by bilateral interrelationships, unlike the UK, Denmark and Sweden, which seem to be quite isolated from other EU countries. The authors also show that changes in ratings calculated by rating agencies are triggered by sovereign bond markets rather than the other way around, but a downgrade affects neighboring markets more than the domestic one.

Thus, although the above-mentioned papers included Central Europe in their datasets, to the best of our knowledge scarcely any paper concentrates specifically on Central Europe and the reasons for the growth of sCDS spreads in 2010. We would like to fill this gap and concentrate on the impact of pan-European turmoil on the emerging markets by extending our previous research, i.e. Kliber (2011).

Since the model presented in Kliber (2011), which included only regional effects, was unable to explain the periods of volatility growth (especially in Poland and the Czech Republic), we extended the sample and included factors from outside of the region in the model. We observed the common growth of CDS prices in the periods corresponding to the crisis in the Mediterranean region and thus we decided to check the reaction of Central European CDS prices to this event. The results of the research suggest that the growth of volatility can be explained either by the Hungarian crisis or the Greek one, but only the extreme events in the Greek market contributed to the growth of correlation between the Polish and Hungarian markets and, to a lesser extent, between the Czech and Hungarian markets.

The remainder of this paper is structured as follows: first, we briefly discuss the contagion and co-movement definitions. We then present the data and discuss the relationships between two measures of sovereign risk—the sCDS and government bonds. In the next section after that, we introduce the methodology used in the research. Finally, by computing estimates of CDS volatilities on the basis of multivariate SV models, we investigate the reaction of the pairs Poland-Hungary and the Czech Republic-Hungary to the European, Southern European (i.e. Greek crisis) and domestic (Hungarian crisis) events by means of modeling their dynamic correlation including explanatory variables. Since the yield of sovereign bonds is yet another indicator of the insolvency risk of the given country, as an approximation of the European volatility we use the squared returns of German ten-year bonds, Southern European (Greek) bonds[1] and Central European (Hungarian) bonds.

The paper is an extension and continuation of the Kliber (2011) study. While in the previous paper we concentrated only on interregional dependencies, here we are looking for the external sources of excessive volatility. The time span of the research

[1] Additionally, Arghyrou and Kontonikas (2012) showed that Greek bonds can be treated as a proxy for EMU (European Economic and Monetary Union) specific risk.

remains the same. The results obtained in the new study support and extend the previously obtained conclusions.

2. Volatility Spillovers, Contagion and Interdependence

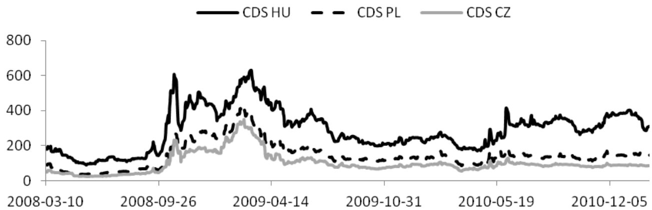
Most researchers agree that volatility transmission (spillover) mechanisms can lead to the propagation of crises among countries. Spillovers can be detected using various methods. Diebold and Yilmaz (2011) propose a volatility spillover index computed on the basis of the decomposition of an error matrix obtained after fitting the VAR model. Other authors use multivariate volatility models (e.g. Teräsvirta and Nakatani, 2009; Yu and Meyer, 2006; and many others). The so-called causality-in-variance tests (Cheung and Ng, 1996; Hong, 2001; Hafner and Herwartz, 2008) are yet another method.

These methods help us to detect volatility spillovers regardless of their basis. However, depending on the source of spillovers, it is possible to classify them as, for instance, contagion or co-movement of fundamentals. Contagion itself has many definitions. Usually it is defined as the "transmission of a crisis to a particular country due to its real and financial interdependence with countries that are already experiencing the crisis" (see also Calvo and Reinhard, 1996). Some authors argue, however, that we can talk about contagion only if the economies are not linked through trade, bank loans or other investment flows (see Forbes, 2012) and that only residual (non-fundamental) transmission of shocks can be defined as contagion. Others point out that only sunspots (see Fratzscher, 2003), i.e. contagion due to the irrational behavior of investors, can be called contagion *sensu stricto*. Some other authors suggest dividing contagion into different categories according to its cause. For instance, Masson (1999) suggested dividing contagion effects into three categories: *monsoonal effects* (driven by a common cause affecting all of the countries, e.g. a change in US monetary policy), *spillovers* (macroeconomic linkages among countries, mainly through trade flows) and other causes not related to the given countries' economic fundamentals, i.e. *pure contagion*.

Pericoli and Sbracia (2003) present probably the most comprehensive set of definitions of contagion, such as "contagion occurs when volatility spills over from the crisis country to the financial markets of other countries", while noting, however, that such behavior may be a simple cause of normal interdependence of markets. Such a case was considered by Forbes and Rigobon (2002), who provide the strictest definition of contagion, stating that it occurs only if the linkages between the analyzed markets intensify significantly during a crisis. In other cases, the relationship between markets should be called *interdependence*. Forbes and Rigobon use correlation to measure the strength of relationships between markets. However, this is not the only possibility. The definition is strict in the sense that it enables us to determine contagion on the basis of the strength of linkages before and after a crisis. However, it does not indicate how to measure these relationships. The most commonly employed tests utilize correlation coefficients.[2]

[2] However, some researchers use additional measures. Causality is an example here. For instance, Sander and Kleimeier (2003) and Gomez-Puig and Sosvilla-Rivero (2011) determine contagion based upon "an abnormal increase in the number or in the intensity of causal relationships compared with that of tranquil period, triggered by an endogenously detected shock".

Figure 1 Dynamics of Sovereign CDS Prices in Central Europe during the Period March 2008–March 2011



Source: Bloomberg database.

In our research, we will look for possible sources of volatility growth in the Central European countries which came from outside of the region. We will be interested in whether the impact of the Greek or pan-European crisis on the risk perception of Central European economies can be classified as the *monsoonal effect*. Bearing in mind the definition provided by Forbes and Rigobon (2002), while looking for the external sources of volatility growth we will control not only for changes in volatility, but also for changes in correlation.

3. Sovereign CDS Prices—Data

In *Figure* 1, we present the evolution of five-year CDS premia (i.e. the spread) in Central Europe over the period from March 10, 2008 to March 9, 2011. The data is taken daily and was provided by the Bloomberg database. We decided to limit the analysis to three Central European economies: the Czech Republic, Hungary and Poland. Slovakia was excluded from the set due to the fact that since 2009, the euro has been the official Slovak currency. Thus, the dynamics of the series could have been influenced by an additional factor, starting from the above-mentioned time point, and since the Slovak economy is exposed to quite different sources of risk, we decided not to bias the analysis. Therefore, we concentrated only on those Central European countries that had retained their own currencies up to the time of the research.

The availability of the data is limited, since the market is fairly "young". The modern credit derivatives market started to develop in the 1990s and saw rapid growth from the mid-1990s until the end of 2007 (see Chaplin, 2010). The most common credit derivative is the credit default swap. In the case of Central Europe, the development of the market dates back to 2008 (there had previously been almost no turnover in the market). The most liquid contracts are five-year CDS (see Augustin, 2014) and thus we concentrate on the instruments of this particular maturity.

Table 1 presents the descriptive statistics of the CDS data. We can observe that the Hungarian instruments seem to be the most volatile ones. They are characterized by the highest unconditional standard deviation as well as the highest spread between the maximum and minimum values. Moreover, we obtain negative kurtosis only in the case of Hungary.

The spread of the Hungarian CDS takes the highest values, which means that the market ranks investment risk in the country as the highest in the region. It is also clear that the CDS spreads react very sensitively to international events. We observe

Table 1 Descriptive Statistics of the CDS Prices

	mean	standard deviation	minimum	maximum	median	skewness	kurtosis
CDS CZ	101.00	58.59	25.25	350.00	89.72	1.79	3.73
CDS HU	194.27	117.00	88.50	629.76	284.98	0.86	-0.26
CDS PL	145.00	73.40	32.00	415.00	137.51	1.13	0.15

two periods in which prices took significantly higher values. The first one corresponds to the outbreak of the crisis throughout Europe. Although the moment of the Lehman Brothers collapse, which is considered to be a critical moment in the evolution of the crisis, did not cause an immediate growth in the spread, we observe a long period of risk growth, from late October 2008 to the middle of 2009. The events which contributed to the growth of the spreads in autumn 2008 included the speculative attacks on Central European currencies, the downgrades of country ratings by rating agencies and domestic problems connected with the outbreak of the crisis in Europe (worsening trade conditions, confidence crisis among domestic banks due to the bankruptcy of foreign banks, etc.).

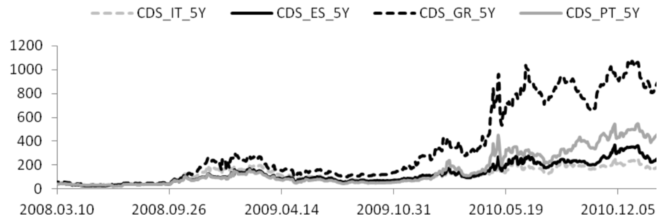
According to the Financial Stability Report (National Bank of Poland, 2009), "the rise in the CDS premium on Polish government debt was largely connected with the global tendency to assess credit risk very prudently and the negative impact of the situation in the region on the perception of investment risk in Poland". According to this report, the rating implied by the CDS prices was BBB, while Moody's assessment was A2 and S&P's and Fitch's were A-. In the case of Hungary, the rating was lowered several times in 2008 and 2009 (e.g., on October 15 and November 17, 2008, and March 30, 2009). However, changes in the rating were quite rare and were not as sharp as suggested by the dynamics of CDS prices (see also Kliber, 2011).

Starting in 2009, the situation in Central Europe started to stabilize, which may have been a direct consequence of the announcement of the European Stabilization Mechanism on May 9 of that year. Shortly afterwards, the risk assessment of Central European bonds improved (National Bank of Poland, 2010) and we could observe a period of relative price stability up to the spring of 2010, when the CDS prices rose again. This turmoil may have had two reasons—the first one could have been the Greek crisis, while the other one was perhaps the result of regional linkages and the consequence of the problems in Hungary.

3.1 The Greek Crisis

The stability and credibility of Greece started to be questioned as early as at the beginning of 2010. On April 23, 2010, the Greek government requested the activation of an EU/IMF bailout package. Four days later, the rating of Greek sovereign debt was lowered by S&P (and after a while also by Moody's and Fitch) to BB+, and as a consequence the yields on Greek bonds and CDS premia rose sharply. On May 1, the Greek government announced a series of austerity measures and asked for an EU/ /IMF loan package. A three-year loan of EUR 110 billion was promised on the condition that the austerity package would be implemented (see Nelson et al., 2011). The agencies immediately cut Greece's rating. The austerity package was implemented and the loan was provided, yet in the following months the crisis deepened.

Figure 2 Dynamics of Sovereign CDS Prices in Southern Europe over the Period 2008–2011



Source: Bloomberg database.

The austerity measures taken by the Greek government led to strikes and the situation continued to deteriorate (see also Kliber, 2013).

We present the reaction of CDS prices in the Mediterranean region to these events in *Figure 2*. We notice extreme growth, which was much higher than in the first phase of the financial crisis. If we compare the picture with *Figure 1*, we can conclude that the first phase of the crisis was much more severe in Central Europe (spreads exceeded even 600 bp in the case of Hungary and 300 bp in the case of the Czech Republic, while in the Mediterranean region they did not even reach 300 bp in the most hectic phase). Meanwhile, in the second phase we observed a short period of CDS price growth to almost 200 bp in the case of Poland and 140 bp in the case of the Czech Republic, and a long period of rising prices (to as high as 400 bp) in the case of Hungary, while the growth of Greek CDS prices was enormous and exceeded 1,000 bp. The crisis was not so severe in the case of the other countries in the region—Portuguese CDS instruments reached values exceeding 540 bp, but in the case of Spain and Italy growth was even lower than in the case of Hungary (see also Kliber, 2011).

3.2 The Hungarian Crisis

Comparing the dynamics of the Polish and Czech CDS spreads to the Hungarian ones (*Figure 1*), we notice that the growth of the premia in the spring and summer of 2010 was only temporary in the case of Poland and the Czech Republic, while the Hungarian CDS prices remained high until the end of the period under study. Let us now briefly analyze the economic situation of Hungary. As early as on June 3, the leader of the ruling Fidesz party admitted that the country's finances were in much worse condition than had been previously expected. There was only "a slim chance of avoiding a Greek scenario" (according to the vice-chairman of Fidesz; see www.napi.hu). These pessimistic statements probably contributed to the growth of the five-year credit default swaps on Hungarian debt to 320 basis points (see *Figure 1*). To make things worse, on June 12 Moody's changed its rating for Hungary from BAA1 to BAA3 with a negative outlook, and on July 17 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), saying that the country must take action to meet targets for cutting its budget deficits. This decision was reflected in the growth of CDS price in the second half of July. In November, the Hungarian government announced unpopular reforms of the financial system. That event may in turn explain the growth of CDS prices in November 2010 (see also Kliber, 2011).

4. Sovereign CDS versus Sovereign Bonds

Yet another instrument that represents sovereign risk is government bonds. The relationships between sovereign bonds and sCDS have already been widely studied. One stream of research concentrates on the relationships between the so-called bond spread and the sCDS spread, where the bond spread is defined as the difference between the government bond yield and the yield of risk-free bonds in the region. For instance, Coudert and Gex (2010) analyze the price discovery process in CDS and bond markets (both with maturity of five years) in an attempt to determine which instrument leads the other. They analyze sovereign and corporate markets. In the case of low-yield sovereign markets, the authors report that the bond market leads the sCDS one. The situation is opposite in the case of riskier markets. O'Kane (2012), analyzing five-year instruments, found causality from the Greek CDS market to bonds, but not the other way around. He confirmed causality from bonds to the CDS market in the case of France and Italy, but feedback in the case of Portugal and Ireland. Following these researchers, Kliber (2013) analyzed similar relationships in ten-year instruments, confirming among other things that relationships between bonds and the sCDS market can change in high and low volatility regimes.

Büchel (2013) showed that the reactions of bond and sCDS spreads to public statements by ECB and EU officials during the first phase of the crisis were very similar. Badaoui et al. (2014) even observed the substitution effect between liquidity in bond and CDS markets, i.e. when CDS liquidity risk is high, bond liquidity risk is lower and vice versa. Calice at al. (2013a) provided evidence on the important impact of sCDS market liquidity on sovereign bond spreads. Thus, there is convincing evidence that the sCDS and bond markets are closely related one to another.

There appears a question, though, of which market is more linked to a given country's domesic situation: the sCDS or the bond market? There are numerous papers that confirm that the sCDS market is very prone to expectations and that fundamentals explain only a part of the instruemnts' dynamics (see the introductory section and, for example, Longstaff et al., 2011). When it comes to bonds, it is clear that the market is also affected by international events. However, Afonso et al. (2012) found that since 2007 the movements of bond spreads have been well explained by the dynamics of macro and fiscal fundamentals, and since 2009 the range of significant fundamentals has even increased. The results did not change when the authors used sCDS instead of bond spreads.

Kocsis (2013) showed that, although global and regional factors can be clearly derived in the case of sCDS, foreign exchange rates and stock indices, no such factors exists in the case of domestic bond markets.[3] He suggests that this finding could be explained by the fact that different countries have different monetary policies and monetary policy is reflected in bond yields. The author shows that in the case of Hungary the idiosyncratic factor can explain up to 80% of the variance of bond yields, while in the case of sCDS this figure is only 33%. Besides, in the case of sCDS market global and regional events can explain 43% and 21% of variance,

[3] Similar results were obtained by Kliber and Będowska-Sójka (2013), where in principal component analysis of bond spreads the first component explains only 38% of comon variance, while the first three components can explain only 70% (compared to indices, where the first component explains 75% of common variance).

respectively. This suggests that foreign events are more important than domestic events in determining these indicators. On the other hand, the large unexplained variance of bond markets may indicate a larger role of domestic policy.

Since bond yields should represent domestic factors better than sCDS, we decided to use them to construct proxies of the Greek and Hungarian crises. As German bond yields are used as a proxy for the risk-free rate in Europe (see, for example, Coudert and Gex, 2010 or O'Kane, 2012), we also used German bonds to construct a proxy for European risk.

5. Methodology

The aim of our research was to verify to what extent the prices of the CDS instruments in Central Europe were determined by regional events as well as by the European situation. To check this, we verified the international cross-dependencies, applying the Yu and Meyer (2006) multivariate stochastic volatility model with dynamic conditional correlation (hereinafter referred to as the "DC-MSV model"). We applied the model to the following pairs: Poland-Hungary and the Czech Republic-Hungary. This allowed us to obtain estimates of volatilities and of conditional correlation. If growth of volatility in both markets is accompanied by correlation growth, we conclude that contagion occurred. If the correlation does not change, we conclude that the markets are interdependent. The motivation of our approach was the definition of contagion and interdependence given by Forbes and Rigobon (2002).

In order to have better insight into the nature of the relationships between the markets, we modified the model by introducing some additional explanatory variables into the covariance function of the instruments. Namely, we wanted to determine what factors may have influenced conditional variances and correlation, and to determine the sources of potential volatility and correlation growth of the instruments. If we observe common growth of volatility of the pair of instruments, then should we attribute it to the Greek or Hungarian crisis or simply to the common volatility growth in the region? If we observe common growth of correlation, then was it caused by the Greek or Hungarian crisis? Studying the values and significance of the explanatory variables allows us to answer the following questions: what events contributed to the growth of volatility in Poland and the Czech Republic and what contributed to volatility growth in Hungary? What was the impact of the Hungarian crisis on the volatility of Polish and Czech CDS? Did the Hungarian crisis contribute to the growth of correlation between Hungary and Poland or Hungary and the Czech Republic or, conversely, did it result in breaking the relationships? What was the impact of the Greek crisis on the volatility of Polish and Hungarian CDS prices? What was the impact of the European turmoil and was it distinguishable from the Greek crisis?

Therefore, we needed variables that could approximate the volatilities of the Hungarian, Greek and German markets. For the reasons described in the preceding paragraph, we decided to use bond yields to construct proxies of the volatilities of individual countries.[4]

Let us denote the vector of the mean-adjusted CDS prices with $\mathbf{y}_t$. In the first part of the study, the $\mathbf{y}_t$ vector consists of Polish and Hungarian sCDS prices, Czech and Hungarian sCDS prices in the second part. Let us also assume that it can be modeled as a process of $\boldsymbol{\varepsilon}_t$:

$$\mathbf{y_t} = \mathbf{\Omega_t \varepsilon_t}$$

where $\mathbf{\Omega_t} = diag\left(\exp\left(\frac{h_t}{2}\right)\right), \mathbf{\varepsilon_t} \mid \mathbf{\Omega_t} \sim N\left(\mathbf{0}, \mathbf{\Sigma_{\varepsilon,t}}\right)$ and $\mathbf{\Sigma_{\varepsilon,t}} = \begin{pmatrix} 1 & \rho_t \\ \rho_t & 1 \end{pmatrix}$. The volatility of the CDS prices, $\mathbf{h_t}$, is modeled as an autoregressive process:

$$\mathbf{h_{t+1}} = \mathbf{\mu} + diag\left(\phi_{11}, \phi_{22}\right)\left(\mathbf{h_t} - \mathbf{\mu}\right) + \mathbf{\eta_t}$$

where $\mathbf{\eta_t} \sim N\left(\mathbf{0}, diag\left(\sigma_{\eta 1}^2, \sigma_{\eta 2}^2\right)\right)$. Finally, the conditional correlation of $\mathbf{\varepsilon_t}$ is equal to

$$\rho_t = \frac{\exp\left(q_t\right) - 1}{\exp\left(q_t\right) + 1}$$

where q_t also follows the autoregressive process:

$q_{t+1} = \psi_0 + \psi\left(q_t - \psi_0\right) + \sigma_\rho v_t$ and $v_t \sim N(0,1)$.

The model was presented in Yu and Meyer (2006) as multivariate stochastic volatility model with dynamic conditional correlation (DC-MSV). The model is analogous to multivariate GARCH (generalized autoregressive conditional heteroskedasticity) models with dynamic conditional correlation. The conditional correlation is also modeled as an autoregressive process $\left(q_t\right)$ and normalized to take values from the (-1;1) interval $\left(\rho_t\right)$.

In order to test the impact of external events on the volatility of the Polish and Hungarian CDS prices, we introduced an additional explanatory variable into the variance equation. The variable was constructed on the basis of the yield of German ten-year government bonds (the source of the data was stooq.pl) by taking squares of their returns. The yield of German bonds is used as an approximation of the risk-free rate in the European market (see, for instance, Coudert and Gex, 2010). Squares of the bonds' returns approximate their volatility, and thus risk associated with the safest investment in Europe.

In addition to that, we introduced in the same way two more measures that serve as a proxy of the volatility of the Greek and Hungarian markets. Thus, the modified volatility equation will have the following form:

$$\mathbf{h_{t+1}} = \mathbf{\mu} + diag\left(\phi_{11}, \phi_{22}\right)\left(\mathbf{h}_t - \mathbf{\mu}\right) + \mathbf{\beta} z_{i,t} + \mathbf{\eta_t}$$

where $z_{i,t}$ are the regressors representing the volatility of the European, Greek and Hungarian markets, given by:

[4] Another possibility was to use the squares of the sCDS premia. However, this would be problematic in the case of the Greek market (the sCDS exhibit a lot of extreme values and are very difficult to model). Moreover, inroducing the squares of Hungarian sCDS returns into the Hungarian volatility equation may seem controversial. Squares of the returns are yet another proxy for volatility. Doman and Doman (2004) show that if such a measure of volatility is used as the explanatory variable in the SV model, the two approximations of "real" volatility almost rule-out one another. Koopman et al. (2005) showed also that including realised volatility into the SV equation improves the the model's fit. However, we do not have acces to the sCDS seam-daily data, which would justify this approach.

$$z_t = 100 \cdot \left(P_t - P_{t-1}\right)^2$$

where P_t denotes the yield of the respective bond. Additionally, to avoid computational problems, the highest value of the series obtained in the case of Greece was replaced was a value ten times smaller while still remaining the highest value in the sample (see Section 6 and *Figure 5* for details).

The rationale of the approach is as follows: if coefficient β_i is significant, this means that $z_{i,t}$ significantly influences the volatility of the instrument. If it takes positive values, this means that it contributes to the volatility growth. Since in the Bayesian approach β_i is a stochastic variable, we will analyze its density. If 95% of its probability mass does not cover 0, we will conclude that the variable $z_{i,t}$ is significant.

In order to test the influence of the pan-European, Greek and Hungarian crises on the covariance of the chosen pair of Central European CDS prices, we decided to modify the equation for q_{t+1} by introducing additional explanatory variables—proxies for the Greek and Hungarian volatilities:

$$q_{t+1} = \psi_0 + \psi\left(q_t - \psi_0\right) + \sigma_\rho v_t + \beta_{EU} d_{1t} + \beta_{GR} d_{2t} + \beta_{HU} d_{3t}$$

The variables d_{it} are constructed in such a way that they take the value of 0 up to January 2010, while afterwards they are equal to the ratio of the current value of the respective z_t to the maximal value of the z_i series in the whole analyzed period:

$$d_{\bullet,t} = \frac{z_{\bullet,t}}{\max\left(z_{\bullet,1}, \ldots, z_{\bullet,T}\right)}$$

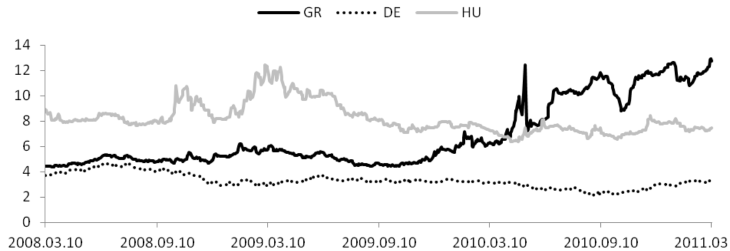
where t is later than January 1, 2010, and 0 otherwise.

Such a construction would allow us to distinguish the influence of the two crises of 2010 on the correlation of both instruments. Again, if coefficient β_i is significant, this means that d_{it} significantly influences the correlation of the instrument. If 95% of its probability mass concentrates on positive values, we conclude that it contributes to correlation growth. All of the priors of beta parameters were non-informative beta. The estimation was performed using WinBUGS (see also Meyer and Yu, 2000).

6. Testing for the Influence of International Events on Central European CDS Prices

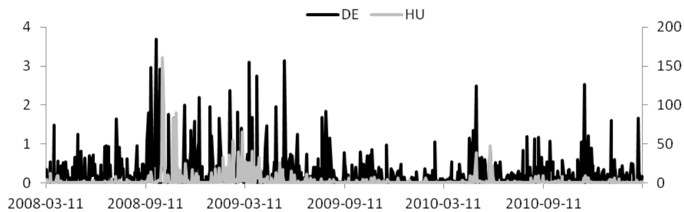
So far we have observed the moments of CDS price growth during international turmoil (e.g., the pan-European growth of prices after the fall of Lehman Brothers and during the Greek crisis)—see *Figures 1* and *2*. We have also observed that the spreads of Polish and Czech sCDS behaved differently than the Hungarian spreads during the evolution of the Hungarian crisis (see the dynamics of the spreads in *Figure 1*). The Hungarian crisis overlapped the Greek one. Thus, it was natural to verify to what extent the "outside-of-the-region events" affected the dynamics of the instruments. To what extent was the CDS price growth caused by the Hungarian crisis, and what was the impact of the Greek crisis on the co-movement of sCDS prices?

Figure 3 Yield of Ten-Year Greek (black solid line), Hungarian (grey solid line) and German (dotted line) Bonds



Source: stooq.pl.

Figure 4 Proxy of the Volatility of German (black line, left axis) and Hungarian (gray line, left axis) Markets—Explanatory Variables Included in the Variance Equation



6.1 Construction of the Explanatory Variables Included in the Variance Equation (F3)

Our hypothesis is that the Greek and Hungarian crises affected the conditional covariance of the instruments. To verify this statement, we apply the DC-MSV model of Yu and Meyer (2006) to the following pairs: Poland-Hungary and the Czech Republic-Hungary. We extend the model by including additional explanatory variables into the variance equation. Thus, we constructed a series of proxies of the volatility of the European, Greek and Hungarian markets. In the case of Europe and Hungary, we used the yields of the government ten-year bonds (German and Hungarian), and took the squares of their returns. The obtained series are presented in *Figure 4*. Since the dynamics of the Greek bonds were very hectic, we had to cut one of the most extreme values of the returns that caused major computational problems. Thus, we divided the value of the highest return by 10, and it still remained the highest value in the sample. The obtained series are displayed in *Figure 5*. We justify this approach by the fact that we were not interested in the exact values of the Greek CDS spread, but rather in their dynamics.

6.2 Construction of the Explanatory Variables Included in the Correlation Equation

Our goal was to check how international and domestic events affected the volatility and correlation of most series. We estimated two models: one including explanatory variables in the variance equation and the other including additional regressors

Figure 5 Proxy of the Volatility of the Greek Market—explanatory variables included in the variance equation

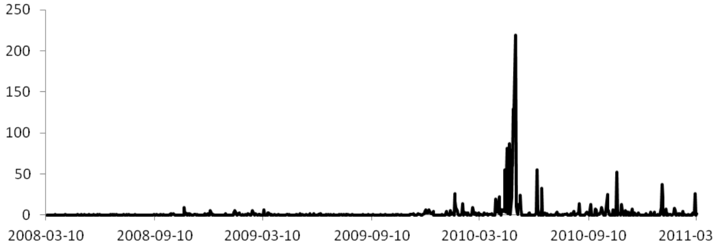
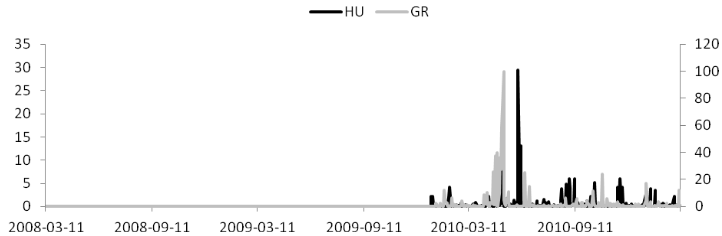


Figure 6 Explanatory Variables Introduced into the Correlation Equation —Proxies of Volatility of the Greek (grey line, right axis) and Hungarian (black line, left axis) Markets—Multiplied by 100



in the correlation equation. Since (on the basis of the previous studies) we are aware of the fact that the conditional correlation between the Central European CDS and the Greek CDS was low over the whole period of the study,[5] we first decided to neglect the first period, i.e., 2008–2010. We suspected that correlation might have grown only temporarily and for brief moments when the problems in Greece intensified. The Greek and Hungarian problems intensified in 2010. Thus, we utilized the previously defined regressors and put zeros in the years preceding 2010. To construct the regressors included in the correlation equation, we computed the ratio of the current squared return to the maximum value of the squared returns (so that the regressors could only take values from the 0–1 interval). In the case of Greece, the maximum value was obtained on May 10, 2010. In the case of Hungary, the maxi-mum value appeared in October 2008, and thus the values of the obtained proxy did not exceed 30% (June 2010)—see *Figure 6*. Eventually, in the case of Germany, the maximum value appeared at the end of September and the values of the obtained proxy were the smallest among all of the values, not exceeding 70% (November 2010).

[5] In fact, the constant correlation test of Engle and Sheppard (2001) suggests that there is no justification for the estimation of any model with dynamic conditional correlation for the pairs Poland-Greece, the Czech Republic-Greece and Hungary-Greece. Constant conditional correlation obtained from the CCC-GARCH (constant conditional correlation GARCH) model of Bollerslev (1990) amounted to -0.11 in the case of Poland-Greece, and -0.15 in the case Hungary-Greece. The computations were performed using OxMetrics6.1 with the G@RCH package.

Figure 7 Estimates of the Volatilities and Correlation between Polish and Hungarian CDS prices (DC-MSV Model, Explanatory Variables in Variance, No Explanatory Variables in Correlation)
Left axis: volatility of the instruments; right axis: correlation

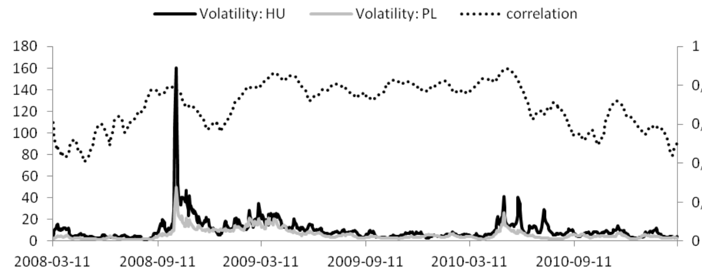
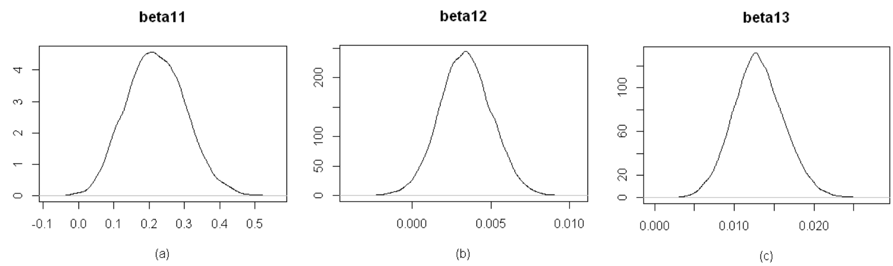


Figure 8 Densities of Beta Parameters in the Volatility Equation for Polish CDS: (a) Impact of the European—beta11, (b) Greek—beta12 and (c) Hungarian—beta13 Crises on the Volatility of Polish CDS



6.3. Results of the Models

In the next step, we estimated a series of DC-MSV models with some additional explanatory variables in the conditional variances and correlation. For the sake of consistency, we present the results obtained for the Hungary-Poland pair (the results for the Czech Republic-Hungary pair with explanatory variables in the conditional variance equation are available upon request). We interpret the beta parameter as significant on the condition that 0 is excluded from the 95% probability interval.

We present the obtained estimates of conditional correlation and variances in *Figure 7* (model with explanatory variables in variance equation). We observe that the correlation (right axis) remained high during the whole period under study. However, there was a significant decline in the summer of 2010.

Figures 8 and *9* present the estimates of the densities of beta parameters. On the basis of the results we can conclude that in the case of the volatility of Polish and Hungarian CDS, the growth of volatility of Greek, German and Hungarian instruments contributed to its growth. Densities of the parameters representing the volatility of Europe as a market tend to concentrate on the highest values (about 0.2 in both cases), since the proxies of the German (European) market volatility take the smallest values. The density of the beta13 parameter (the impact of the Hungarian crisis on the volatility of Polish CDS) concentrates on lower values than the density

Figure 9 Densities of Beta Parameters in the Volatility Equation for Hungarian CDS: Impact of (a) European—beta21, (b) Greek—beta22 and (c) Hungarian—beta23 Crises on the Volatility of Hungarian CDS

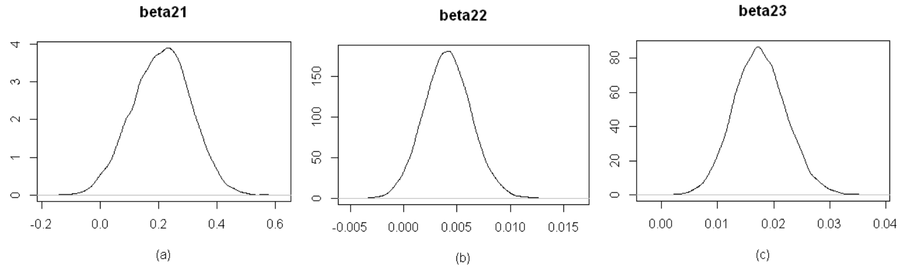
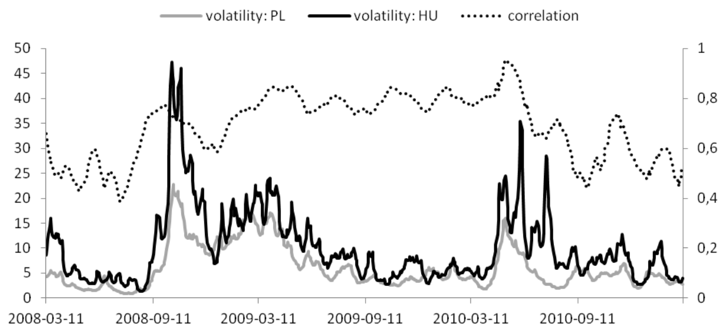


Figure 10 Estimates of the Volatilities and Correlation between Polish and Hungarian CDS Prices (DC-MSV Model, Explanatory Variables in Correlation, No Explanatory Variables in Variance)
Left axis: volatility of the instruments; right axis: correlation



of beta23 (the impact of the Hungarian crisis on the volatility of Hungarian CDS), which means that the Hungarian crisis affected the volatility of the Polish CDS premia to a lesser extent than those of the Hungarian ones. However, in both cases the densities concentrated on values different from zero, which means that their impact was significant. Finally, the impact of the Greek crisis seems to have affected the Polish CDS premia to the same degree as the Hungarian ones (the densities of parameters beta12 and beta22). The same conclusions can be derived for the Czech Republic-Hungary pair.

Let us now analyze the impact of the events on the correlation between Polish and Hungarian instruments. The patterns of volatilities and correlation remain approximately the same, though the values taken by the volatilities are much smaller in comparison to the previous model and the correlation changes are more dynamic (see *Figure 10*). What is most interesting, however, is the analysis of the coefficients representing the impact of European, Greek and Hungarian risk on the correlation (*Figure 11*). Let us recall that we analyzed risk in the second phase of the crisis starting in 2010. On the basis of the results, it can be stated that the peaks in variance of neither the Hungarian nor German (European) CDS market contributed to the changes in correlation dynamics. Although we observe a gradual decline of correlation between

Figure 11 Densities of Beta Parameters in the Correlation Equation for Hungarian and Polish CDS:
Impact of the (a) European, (b) Greek, and (c) Hungarian Crises on the Correlation between Poland and Hungary

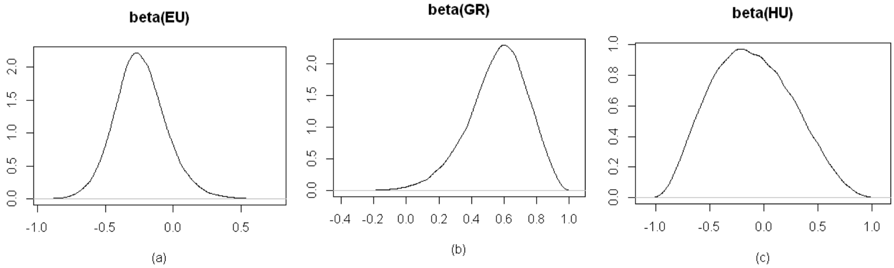
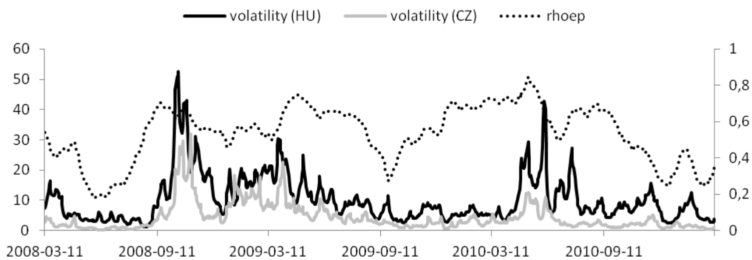


Figure 12 Estimates of the Volatilities and Correlation between Czech and Hungarian CDS Prices (DC-MSV Model, Explanatory Variables in Correlation, No Explanatory Variables in Variance)
Left axis: volatility of the instruments; right axis: correlation

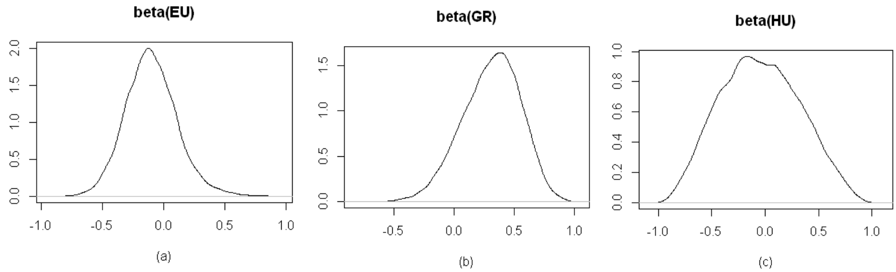


the Polish and Hungarian CDS markets, the separate extreme changes in neither market influenced this pattern.

However, it seems that the extreme values of volatility in the Greek CDS market contributed to the growth of correlation between the Polish and Hungarian markets (the probability mass of the respective coefficient concentrates on positive values and the density function is clearly right-skewed). This common reaction to the changing situation in the third market suggests the *monsoonal effect*.

In the case of the Hungary-Czech Republic pair, the model with explanatory variables in correlation reveals that the correlation between the markets is, on average, lower than in the case of Poland and Hungary and its changes are more hectic. Again, with the development of the Hungarian crisis, the correlation diminished (*Figure 12*). The densities of the beta parameters are presented in *Figure 13*. It is clear that neither the impact of Hungarian extreme values nor of the pan-European ones influenced the correlation between the Czech Republic and Hungary. The 95% probability interval for the Greek-beta includes zero as well, but density is concentrated mostly on positive values and is right-skewed. Thus, we can expect that to some extent the shocks from Greece could have positively influenced the correlation between the Czech Republic and Hungary.

Figure 13 Densities of Beta Parameters in the Correlation Equation for Hungarian and Czech CDS: Impact of the (a) European, (b) Greek, and (c) Hungarian Crises on the Correlation between Czech and Hungary



The conclusions are obvious: there was no contagion from Hungary to Poland or the Czech Republic, according to the Forbes and Rigobon definition. The problems in Hungary affected the volatility of the Polish and Czech CDS prices, but did not affect correlation, and thus we can talk only about co-movement. The volatility growth in the spring of 2010 was caused by the growth of nervousness on the market due to the problems in Greece and Hungary. At that time neither Poland nor the Czech Repulic experienced a crisis in the banking or fiscal sector (see also Komárková et al., 2013).

At the beginning of the Hungarian crisis, the conditional correlation between the Polish and Hungarian markets remained approximately constant—see *Figures 7* and *10*. Next, we observe that the volatility of the Hungarian CDS premium remained high, while the volatility of the Polish CDS premium decreased together with the correlation between the markets. In the case of Hungary- Czech Republic pair, the correlation grew in the calm period (beginning of 2010), but when Hungary entered the crisis, the volatility of the Czech CDS reacted only mildly, while the correlation remained constant. After a short period of slight Czech volatility growth, the situation in the Czech market stabilized and the correlation with Hungary diminished. Thus, at the beginning of the Hungarian crisis we can talk about co-movement, while a few months later the relationships ended.

6.4 Robustness Check

To check the robustness of the results, we decided to construct analogous proxies of selected markets' volatility using sCDS instead of bond yields. In the case of the Poland-Hungary pair the main conclusions still hold. The Greek crisis contributed to the growth of correlation between the Polish and Hungarian sCDS markets (the values taken by the beta are smaller but still positive), while the impact of Hungarian and pan-European turmoil was negligible. In the case of Hungary-Czech Republic, the MCMC algorithm did not reach convergence.

7. Discussion and Conclusions

In this article we presented an analysis of the dynamics of some Central European sovereign CDS prices. The author took into account the Czech Republic, Hungary and Poland. On the basis of the results of the test (the Yu and Meyer DC-MSV model with explanatory variables in conditional variance and correlation), we conclude that the growth of sCDS volatility in Central Europe can be attributed both to European and regional events.

We have observed significant growth of volatility of the Polish and Hungarian CDS as a response to the Greek problems, although the economic linkages between Central and Southern Europe are not expected to be as strong as the relationships within the regions. It is worth noting that the same reaction to the Greek crisis was also documented in Western Europe, e.g. in Germany and France. However, banks in France and Germany had the biggest exposure to Greek debt, which could justify the growth of the CDS premia together with the beginning of the Greek problems.[6] The exposure of Central European banking systems to Greek debt was relatively small. Nevertheless, the results of the study suggest a reaction of the Polish, Czech and Hungarian CDS markets to the Greek problems. This confirms that expectations do play a role in pricing CDS contracts. Although Central Europe is not vitally linked to Southern Europe and the fundamentals in Poland and the Czech Republic did not weaken significantly during the Greek crisis, the rise of the CDS prices can only be explained by expectations. This result is in line with the conclusions of Longstaff et al. (2011), who argue that fundamentals do not play a very important role in CDS pricing. On the basis of the results of this study and our knowledge about the economic relationships among the analyzed markets, we can also suppose that the Greek crisis influenced the risk perception of Western European countries (financial contagion) and then spread to Central Europe in the form of the *monsoonal effect*.

The results also support the findings by Kocsis (2013), who found that Poland and Hungary are linked through the global factor. If that is true, the fact that the shocks coming from the Greek market contributed to the growth of correlation between the Polish and Hungarian CDS markets is not surprising.

However, the decline of correlation between Poland and Hungary, as well as between the Czech Republic and Hungary, was caused by the sole volatility growth of the Hungarian sCDS prices. Since the growth of volatility—as a response to the Hungarian problems—was not accompanied by correlation growth, we conclude that there was no sunspot-driven contagion from Hungary to Poland, nor from Hungary to the Czech Republic (although we did observe volatility spillovers). The conclusions are fairly optimistic: despite quite severe problems in the European Union and in the rest of the world, investors value the sovereign risk of Central European countries separately on the basis of the fundamentals rather than on the basis of the situation of the weakest country in the region.

[6] However, as Ardagna and Caselli (2012) point out, the Greek government bond market is so small that even such exposure could have hardly threatened the solvency of financial institutions in France or Germany.

REFERENCES

Adam M (2013): Spillovers and Contagion in the Sovereign CDS Market. *Bank and Credit*, 44(6): 571–604.

Afonso A, Arghyrou MG, Kontonikas A (2012): The Determinants of Sovereign Bond Yield Spreads in the EMU. *University of Glasgow, Business School-Economics, Working Papers*, no. 2012-14. Available at: http://pascal.iseg.utl.pt/~depeco/wp/wp362012.pdf.

Afonso A, Furceri D, Gomes P (2012): Sovereign Credit Ratings and Financial Markets Linkages: Application to European Data. *Journal of International Money and Finance*, 31(3):606–638.

Aizenman J, Hutchison M, Jinjarak Y (2013): What is the Risk of European Sovereign Debt Defaults? Fiscal Space CDS Spreads and Market Mispricing of Risk. *Journal of International Money and Finance*, 34(C):37–59.

Alter A, Schüler YS (2012): Credit Spread Interdependencies of European Sates and Banks during the Financial Crisis. *Journal of Banking and Finance*, 36(12):3444–3468.

Arghyrou MG, Kontonikas A (2012): The EMU Sovereign-Debt Crisis: Fundamentals, Expectations and Contagion. *Journal of International Financial Markets, Institutions and Money*, 22(4):658–677.

Atrissi N, Mezher F (2010): Sovereign Debt Crisis and Credit Default Swaps: The Case of Greece and Other PIIGS. *6th International Finance Conference on Financial Crisis and Governance. Cambridge Scholars Publ.*: pp. 278–289.

Augustin P (2014): Sovereign Credit Default Swap Premia. *Journal of Investment Management*, forthcoming. Available at: http://dx.doi.org/10.2139/ssrn.2055346.

Badoui S, Cathcart L, El-Jahel L (2014): Implied Liquidity Risk Premium in the Term Structure of Sovereign Credit Default Swap and Bond Spreads. *Working paper*: SSRN: http://ssrn.com/abstract=2317966

Broto C, Perez-Quiros G (2013): Disentangling Contagion Among Sovereign CDS Spreads during the European Debt Crisis. *Banco de Espana Documentos de Trabajo*, no. 1314. Available at: http://dx.doi.org/10.2139/ssrn.2341518.

Büchel K (2013): Do Words Matter? The Impact of Communication on the PIIGS' CDS and Bond Yield Spreads during Europe's Sovereign Debt Crisis. *European Journal of Political Economy*, 32: 421–431.

Calice G, Chen J, Williams J (2013a): Liquidity Spillovers in Sovereign Bonds and CDS Markets: An Analysis of The Eurozone Sovereign Debt Crisis. Journal of Economic Behaviour and Organization, 85: 122-143.

Calice G, Miao R-H, Štěrba F, Vašíček B (2013b): Short-term Determinants of Idiosyncratic Sovereign Risk Premium: A Regime-Dependent Analysis for European Credit Default Swaps. *Czech National Bank Working Paper*, no. 13. Available at: https://www.cnb.cz/miranda2/export/sites/www.cnb.cz/en/research/research_publications/cnb_wp/download/cnbwp_2013_13.pdf

Calvo S, Reinhart C (1996): Capital Flows to Latin America: Is There Evidence of Contagion Effects? In: Calvo GA, Goldstein M, Hochreiter E (Eds.): *Private Capital Flows to Emerging Markets after the Mexican Crisis*. Peterson Institute Press, pp. 151–171.

Chaplin G (2010): *Credit Derivatives. Trading, Investing and Risk Management*. 2nd Edition. Wiley.

Cheung YW, Ng LK (1996): A Causality-in-Variance Test and its Application to Financial Market Prices. *Journal of Econometrics*, 72:33–48.

Chobanov P, Lahiani A, Nenovsky N (2010): Money Market Integration and Sovereign CDS Spreads Dynamics in the New EU States. *Wiliam Davidson Institute Working Paper*, no. 1002. Available at: http://www.suerf.org/download/studies/study20113.pdf.

Claeys P, Vašiček B (2012): Measuring Sovereign Bond Spillover in Europe and the Impact of Rating News. *Czech National Bank Working Paper*, no. 7. http://www.cnb.cz/en/research/research_publications/cnb_wp/download/cnbwp_2012_07.pdf.

Coudert V, Gex M (2010): Credit Default Swap and Bond Markets: Which Leads the Other? *Banque de France, Financial Stability Review*, 14:161–167.

Doman M, Doman R (2004): *Ekonometryczne modelowanie dynamiki polskiego rynku finansowego* [Econometric Modeling of the Dynamics of the Polish Financial Market]. Poznan, University of Economics Press.

Forbes K, Rigobon R (2002): No Contagion, only Interdependence: Measuring Stock Market Comovements. The *Journal of Finance*, 57(5):2223–2261.

Forbes K (2012): The 'Big C': Identifying Contagion. *NBER Working Paper*, no. 18465. Available at: http://www.nber.org/papers/w18465.pdf.

Fratzscher M (2003): On Currency Crises and Contagion. *International Journal of Finance and Economics,* 8(2):109–129.

Gentile M, Giordano L (2012): Financial Contagion during Lehman Default and Sovereign Debt Crisis. *Commisssione Nazionale Per Le Societa E La Borsa, Quaderni di FInanza*, 72:7–46.

Hafner CM, Herwartz H (2008): Testing for Causality in Variance using Multivariate GARCH Models. *Annales d'Economie et Statistique*, 89:215–241.

Hong Y (2001): A Test for Volatility Spillover with Application to Exchange Rates. *Journal of Econometrics*, 103:183–224.

Kliber A (2011): Sovereign CDS instruments in Central Europe—Linkages and Interdependence. *Dynamic Econometric Models*, 11:111–128.

Kliber A (2013): Influence of the Greek Crisis on the Risk Perception of European Economies. *Central European Journal of Economic Modelling and Econometrics*, 5(2):125–161.

Kliber A, Będowska-Sójka B (2013): Economic Situation of the Country or Risk in the World Financial Market? The Dynamics of Polish Sovereign Credit Default Swap Spreads. *Dynamic Econometric Models*, 13:87–106.

Kocsis Z (2013): Global, Regional and Country-Specific Components of Financial Market Indicators: an Extraction Method and Applications. *Central Bank of Hungary Working Paper*, no. 3. Available at:
http://english.mnb.hu/Root/Dokumentumtar/ENMNB/Kiadvanyok/mnben_mnbfuzetek/WP_2013-03_final.pdf.

Komárková Z, Lešanovská J, Komárek L (2013): Analysis of Sovereign Risk Market Indicators: The Case of the Czech Republic. *Finance a úvěr-Czech Journal of Economics and Finance*, 63(1): 1–24.

Koopman SJ, Jungbacker B, Hol E (2005): Forecasting Daily Variability of the S&P 100 Index using Historical, Realised and Implied Volatility Measurements. *Journal of Empirical Finance*, 12(3):445–475.

Longstaff FA, Pan J, Pendersen LH, Singleton K (2011): How Sovereign is Sovereign Credit Risk? *American Economic Journal: Macroeconomics*, 3(2):75–103.

Masson P (1999a): Contagion: Monsoonal Effects, Spillovers, and Jumps Between Multiple Equilibria. In: Agenor PR, Miller M, Vines D, Weber A (Eds): *The Asian Financial Crisis: Causes, Contagion and Consequences*. Cambridge University Press.

Masson P (1999b): Contagion: Macroeconomic Models with Multiple Equilibria. *Journal of International Money and Finance*. 18:587–602.

Meyer R, Yu J (2000): BUGS for a Bayesian analysis of stochastic volatility models. The *Econometrics Journal*, 3:198–215.

National Bank of Poland (2009): Financial Stability Report, June 2009.

National Bank of Poland (2010): Financial Stability Report, June 2010.

Nelson RM, Belkin P, Mix DE (2011): Greece's Debt Crisis: Overview, Policy, Responses, and Implications. *Current Politics & Economics of Europe*, 22(4):693–719.

O'Kane D (2012): The Link between Eurozone Sovereign Debt and CDS Prices. *Bankers, Markets & Investors*, 117:29–39.

Pericoli M, Sbracia M (2003): A Primer on Financial Contagion. *Journal of Economic Surveys*, 17(4):571–608.

Teräsvirta T, Nakatani T (2009): Testing for Volatility Interactions in the Constant Conditional Correlation GARCH Model. *Econometrics Journal*, 12(1):147–163.

Yu J, Meyer R (2006): Multivariate Stochastic Volatility Models: Bayesian Estimation and Model Comparison. *Econometric Reviews*, 25:361–384.