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Agata Kliber, Barbara Będowska-Sójka[*]

Economic Situation of the Country or Risk in the World Financial Market? The Dynamics of Polish Sovereign Credit Default Swap Spreads[**]

A b s t r a c t. In the article we examine what determines the Polish sovereign Credit Default Swap dynamics. We consider not only measures of changes of the economic situation of the country, but also the impact of the international data. We find that the dynamics of the Polish sCDSs is very vulnerable to the dynamics of exchange rates, stock indices and bond spreads. These variables allow us to explain its behavior without including variables reflecting economic situation of the country. It is shown that the impact of information inflow is also important.

K e y w o r d s: sovereign Credit Default Swap, Bond spread, Stock Exchange indices, exchange rates, sunspots, volatility transmission, volatility models, principal component analysis, event analysis.

J E L Classification: C22, G14, G32.

Introduction

Credit derivatives were perceived as a successful financial innovation in the 90s. The most common type of credit derivatives are credit default swaps

[*] Correspondence to: Agata Kliber, Poznań University of Economics, Department of Applied Mathematics, Al. Niepodległości 10, 61-875 Poznań, Poland, e-mail: agata.kliber@ue.poznan.pl; Barbara Będowska-Sójka, Poznań University of Economics, Department of Econometrics, Al. Niepodległości 10, 61-875 Poznań, Poland, barbara.bedowska-sojka@ue.poznan.pl.

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(CDS). In a credit default swap one party of the contract buys protection and pays the seller a fixed premium each period, until either default occurs or the swap contract matures. If a default occurs, the seller is obligated to buy back from the buyer the defaulted bond at its nominal value.

The sovereign credit default swaps (sCDS) are financial instruments perceived as a protection against insolvency on debt issued by the sovereign borrower (a country). The protection buyer pays a regular premium, the so-called CDS spread.

During the financial crisis in 2008–2009 investors became concerned about the overall economic situation and as a result sCDS spreads rose sharply. The reason is that the price of the sCDS contracts is believed to represent the risk associated with the country. This is embedded in the nature of the contract, which can be interpreted as a bet on the country default or the "insurance" against the situation that the country would not pay its obligations. If the risk associated with the country grows, the price of the "insurance" must grow as well. CDS contract to some extent may be perceived as an insurance, although it differs in the sense that the protection buyer may receive the payment without suffering any loses. As from the start of global financial crisis sCDS spreads have risen substantially and then dropped almost to the initial level, of particular interest is if these changes of spreads are driven by real economic situation.

Usually the economic indicators are perceived as those that represent the economic situation of the country (see e.g. Kosmidou, 2008). However, most of the indicators are of monthly or quarterly frequency, while the sCDS instruments are traded daily. Therefore, researchers point out that the sCDS premia is very vulnerable to sunspots and expectations and it may not reflect the risk properly (see eg. Longstaff et al., 2005; Longstaff et al., 2011; Plank, 2010). By sunspots we refer to extrinsic variables in the way that contagion is neither caused by the fundamentals deterioration nor by trade relationships. Moreover, the models for sCDS with macro-factors as the explanatory variables are usually capable of explaining about 50% of the sCDS dynamics (see e.g. Plank, 2010). In the case of the Polish market such a model is presented in Kliber (2013b), where the monthly dynamics of sCDS premium is explained by the macro-data of monthly frequency.

In the literature sCDS spreads are highly related to bond spreads and stock prices. Giannikos et al. (2013) find that CDS market dominates other markets in terms of price discovery and that the role of stock market diminishes during the financial crisis. As in case of all other financial instruments, the sCDS premia may be also vulnerable to the macroeconomic events from the American economy (Longstaff et al., 2011). However macroeconomic announcements constitute only a part of all incoming information and are released on the monthly basis. Lamoureux and Lastrapes (1990) use trading volume as a proxy for information arrival time. As trading volume is observable variable it may well provide an approximation of inflow of widely defined information.

This paper contributes to the existing literature in a few aspects. First of all, we focus on the Polish financial market, which is usually neglected in literature. Secondly, we investigate jointly the influence of expectations and fundamentals in sovereign Credit Default Swap pricing. To examine this issue we consider proxies for domestic as well as outside-the-country "fundamentals" and we study also the impact of selected American macroeconomic announcements together with information inflow measure. We focus our study on constructing a model where the explanatory variables could be of daily frequency and simultaneously account for the economic condition of the country. We examine whether the Polish sCDS premia could be treated as an indicator of the true risk of Polish economy.

The remainder of the paper is structured as follows: in Section 1 we show how fundamentals influence the sCDS spreads, in Section 2 we focus on role of expectations in sCDS pricing, while in Section 3 we concentrate on the impact of macroeconomic announcements. We consider Polish sCDS of 5 years maturity over the period March 1, 2008 to May 31, 2013.

1. Interactions of the sCDS Spread with Variables Representing the Economic Situation of the Country (VAR-DCC Model)

Based upon the findings in the literature we decided to include in our dataset the following variables: bond spreads, exchange rate, stock-exchange index and trading volume of the index as a proxy for incoming information. We are aware of the fact that the variables should not be considered as fundamentals *sensu stricto*, since they themselves are prone to sunspot and expectations. However, taking into account data of monthly frequency inevitably would result in loss of information about sCDS dynamics, since the latter are traded daily. Such an approach was proposed in Kliber (2013b) – the author tested vulnerability of monthly sCDS changes and volatility to the changes of such quantities as: unemployment, real wages, government earnings and expenditures, import, export, inflation, terms of trade, internal and external debt. The models were able to explain about 50% of the sCDS variability. This result is similar to ones documented for another economies (see eg. Longstaff et al., 2011). Thus, we decided to use data of daily frequency that reflect the changes of economic situation of Poland, being aware of their imperfections.

The data used in the study comes from Datastream, www.stooq.pl and the CEIC database. Bond spread is computed as a difference between the yield of the given country's bonds and the yield of the bonds of the economy of the lowest risk in the region (see e.g. Coudert, Gex, 2010). In our case the German bonds are considered. Thus, we calculate the spread by subtracting the yield of 10-years German bonds from the yield of Polish 10-years bonds (see Figure 1).

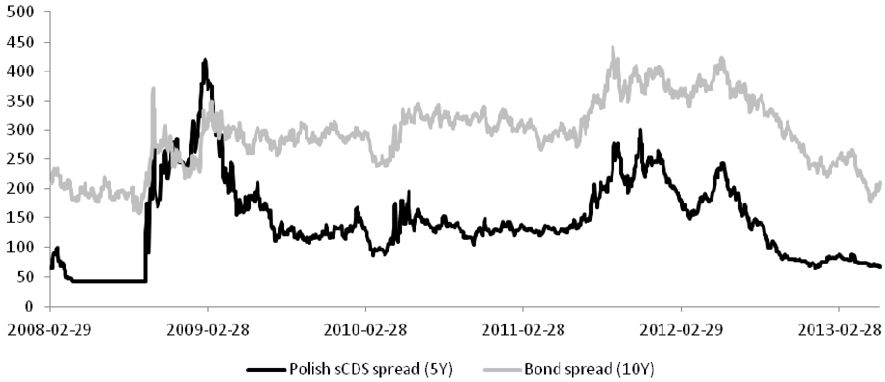

Figure 1. Polish sCDS spread (5 years maturity) and bond spread (10 years maturity)

Since it is said, that the events from American market influence the sCDS spread the most, as an exchange rate we took the USD/PLN one. Eventually, we take into account WIG index as a representative one for the Polish stock exchange, as well as its trading volume. The volume is interpreted as a proxy of the information flow to the market (Figure 2).

Let us stress once again, that we are aware of the fact that the variables are prone to volatility transmission from other markets. From the chosen variables the most immune seems to be the bond-spread, representing the evolution of the risk of Polish treasury bond in comparison with the risk of German bonds.

Since all of the variables are non-stationary, we modeled the log-returns of them. The only exception is volume, where the natural logarithm is obtained. First, we run the VAR model in order to check for any interactions in mean, and in the second step, we estimated the multivariate variance model – DCC(1,1,1,1) of Engle (2002) with Student distribution (see Appendix for details). Table 1 presents the results of the VAR estimation. The number of lags (in our case this is one lag) is chosen via Schwarz information criterion, and the estimation is run in R, package vars (Pfaff, 2008a; Pfaff, 2008b). We used function VAR, and the model was estimated utilizing OLS per equation.

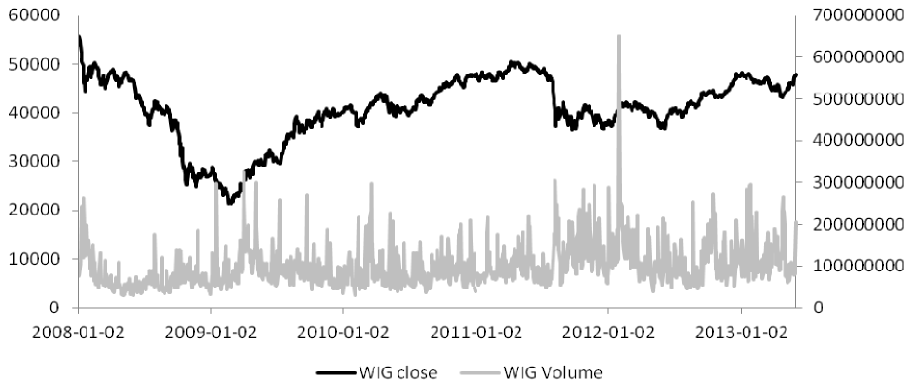

Figure 2. WIG prices and trading volume

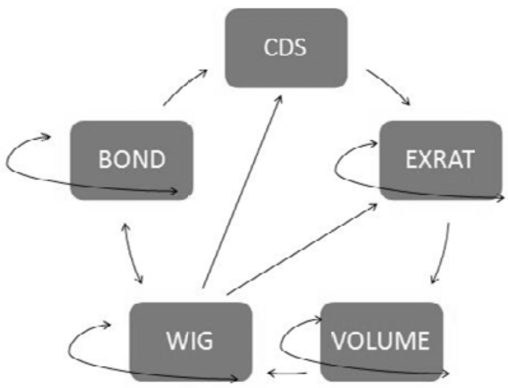

Figure 3. Diagram of dependencies among the economic indicators

The results of VAR estimation are presented in the Table 1. We notice that all the variables interact one with another. In order to make the picture more clear, we present the results also in the separate diagram (see Figure 3). What is very special is that from all of the variables only sCDS changes do not depend on their own previous changes, but are explained by the changes of the other variables from the system. This can suggest that from all of the investigated indicators, they are most vulnerable to changes in expectations about future development of economic situation of the country (if we assume that such information are incorporated in bond prices, exchange rates and stock indices).

In the next step, we estimate the multivariate conditional variance model with dynamic correlation (Engle, 2002), DCC(1,1,1,1) model with Student distribution, for the residuals obtained from the VAR model. Estimation is done in two steps. First, we estimate univariate volatilities (GARCH models), and in the next step – the correlation equation. The estimation was run via OxMetrics6 software with package G@RCH (Laurent and Peters, 2002). The results of estimation are presented in Table 2. As we can see, all the variables (apart from trading volume) are significant in all equations. Also the average values of correlations are significant in the case of each pairs excluding the ones with volume. Absolute values of the correlations are approximately 0.4. In Figure 4 we present the obtained estimates of conditional correlations for each pairs apart from the ones including volume, while in Figure 5 – the estimates of conditional variances.

2. Changes of Economic Situation in the World and Polish sCDS Pricing

In this Section we examine the vulnerability of Polish sCDS prices to the changes of similar indicators from the neighbor countries. Again, we take into account: bond spreads, exchange rates and stock exchange indices. In order to account for as much of the variability of the data as possible and to reduce the number of explanatory variables we decide to use Principal Component Analysis and check the reaction of Polish sCDS prices to the changes of the first principal components of each group of variables.

We calculate the bond spreads assuming again that the risk free rate of the region is represented by the German bonds yield. Based upon the previous studies (Kliber, 2013a) we are aware of the fact that in the case of some countries such spreads in some periods appear to be negative. Hence, we excluded some of the countries from the analysis. Eventually, we took into account the following bond spreads: French and British (so called low-yield Western European countries), Spanish (Southern Europe), Swedish and Finnish (Northern Europe) and Hungarian one (Central Europe). The dynamics of the spreads is presented in Figure 6. At the time of the study Hungary was the country of the highest bond spread, i.e. its risk was the highest among all analyzed countries, compared to the German bonds. We observe also a gradual growth of risk of Spain, which equaled the Hungarian one at the end of the studied period. Yields of bonds in France and UK are very low

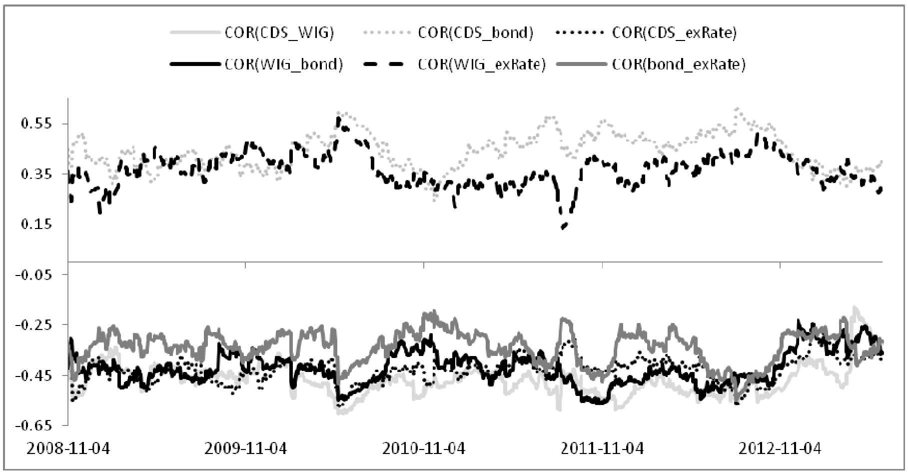

Figure 4. Conditional correlations of CDS spread changes, bond spread changes, WIG returns and returns from USD/PLN exchange rate (DCC model)

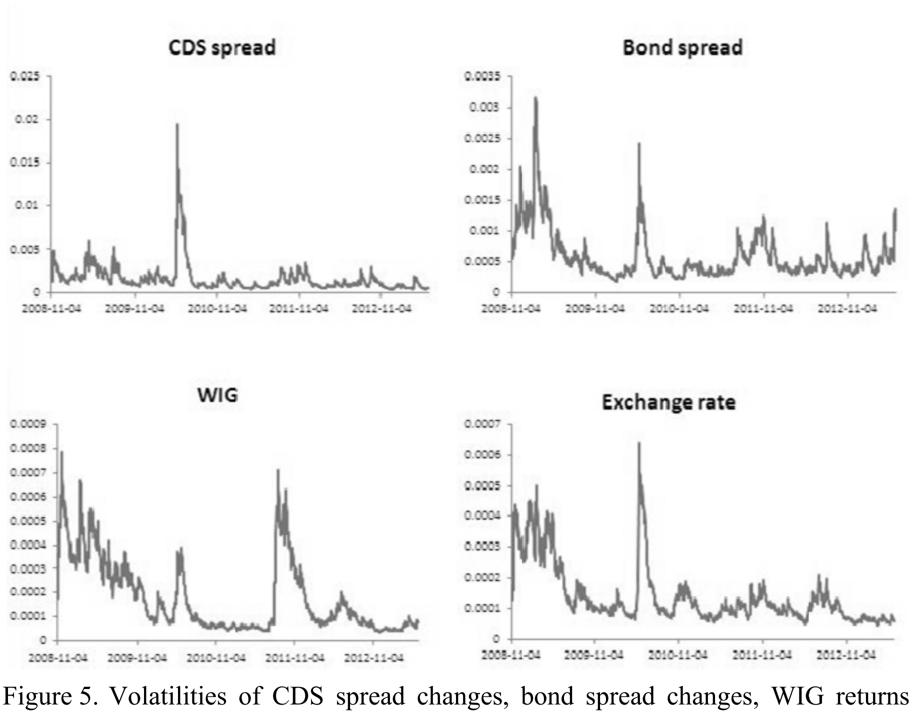

Figure 5. Volatilities of CDS spread changes, bond spread changes, WIG returns and returns of USD/PLN exchange rate (DCC model)

compared to German bonds, while in the Northern European countries the spread is occasionally even negative.

The results of PCA on bond spreads are presented in Table 3. We notice that the first principal component explained only about 40% of the overall variance of the system. The highest loadings in the first component is attributed to Spain, France and Finland, which suggests that the crisis in Southern Europe had indeed an impact on the volatility of the European countries.

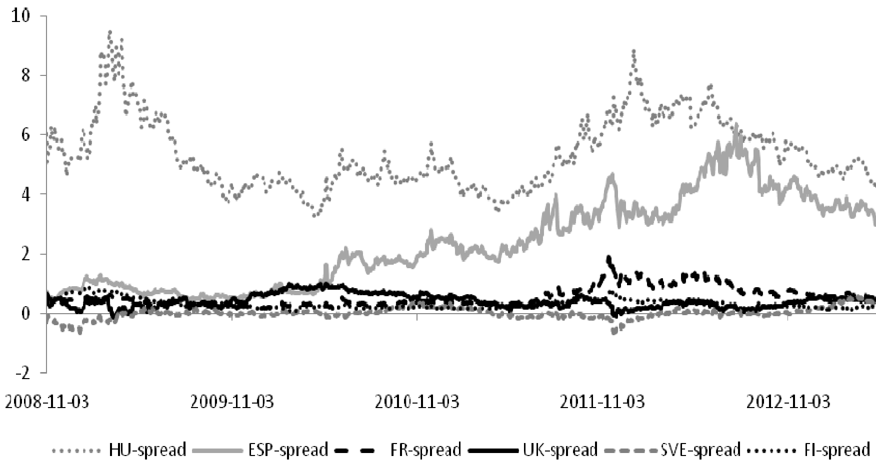

Figure 6. Bond spreads of the selected European countries

From the exchange rates we choose the most representative for the European Union: EUR/PLN, GBP/PLN, SEK/PLN as well as the price of US dollar USD/PLN (see Figure 7). We present the results of Principal Component Analysis in Table 4. In this case the first component has much stronger explanatory power, since it was able to explain 55% of the overall variance of the system. The highest loadings have EUR/PLN, GBP/PLN and SEK/PLN – that is the EU currencies.

Finally, we analyse four stock exchange indices: CAC40, DAX, BUX and S&P500 (see Figure 8). Their dynamics at that time was quite similar, and the first component was able to explain already 75% of common variance (see Table 5).

We conclude that the bond spreads are the most immune to volatility transmission from all of the analyzed indicators of daily frequency, while stock exchange indices are strongly affected by common shocks transmissions.

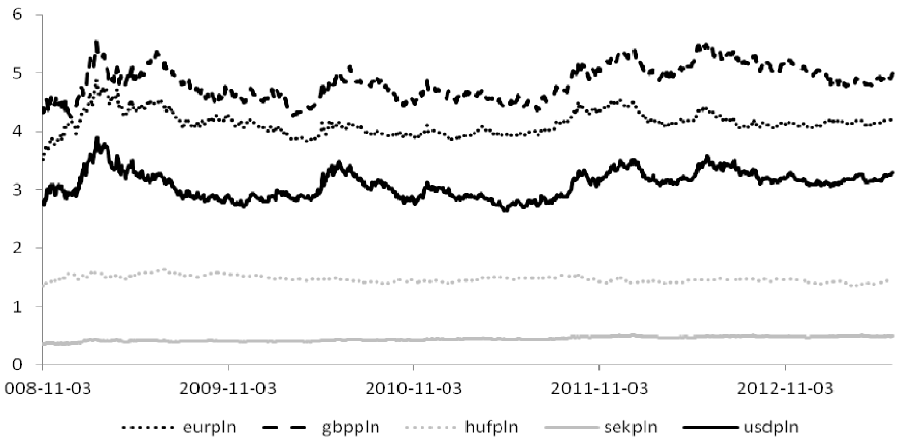

Figure 7. Exchange rates of currencies: EUR/PLN, GBP/PLN, HUF/PLN, SEK/PLN and USD/PLN

After computing the first principal components of each group of factors, we run the series of ARMA-GARCH models (see model (1) in Appendix). In the first model we assume that changes of Polish sCDS are can be explained by the historical values of the spread only (Model 0). In the next one, we add the PC1s as the explanatory variables (Model 1). In the third model we add the explanatory variables used in VAR model from the previous subsection (Model 2). In the third model (Model 3) the previous two are embedded. The results of the estimation are presented in table 6. In all cases the models are estimated via the so called variance-targeting method, i.e. assuming that the ω (see equation 1) is equal to the unconditional variance of the sample. In all cases the values of this parameter are very small. In the case of the conditional mean equation, we introduced the explanatory variables in the form of lagged returns (the exception is the bond spread and the first principal component of bond spreads, which are introduced into the equation at their current values), while the explanatory variables in the volatility equation are the squared lagged returns. In the first step we used also lagged changes of bond spread, however it appeared that the interactions between the sCDS changes and bonds' spread changes are instantaneous. We compare the models on the basis of the log-likelihood function and the information criteria. We follow the Schwarz criterion, since it prefers the models with lower number of explanatory variables and hence we could be sure that the explanatory variables are not redundant.

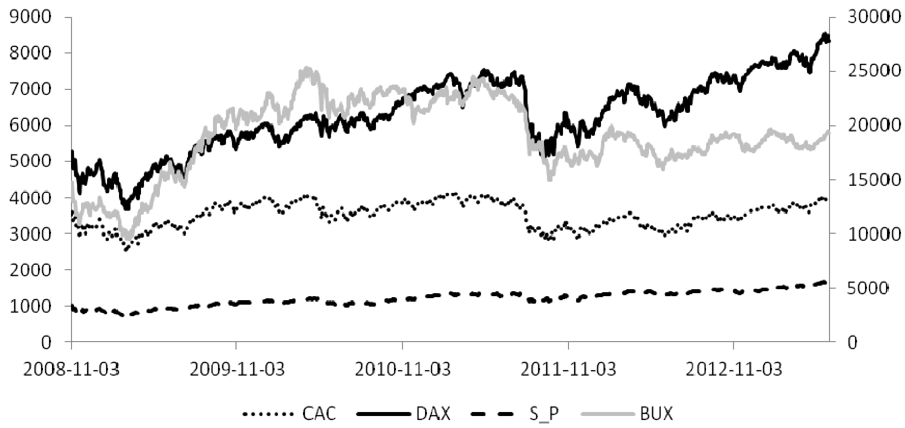

Figure 8. Stock Exchange indices: CAC, DAX, S&P (main axis), and BUX (second axis)

The best model (taking into account the log-likelihood and Schwarz criterion) is the most general one – it includes both the environment (expressed by principal components) and indicators of the country's economic stability. Changes of the spread can be thus explained by the current change of bond spreads of the neighbour countries, as well as the change of domestic bond spread. Additional significant explanatory variables are the lagged values of exchange rates and stock exchange indices, as well as the USD/PLN exchange rate. In the case of the conditional variance equation, the only significant variable is the lagged squared value of WIG returns. We can thus expect the special role of US economy on the risk perception of Poland, as the USD/PLN rate is present in the explanatory variables in two forms: in the PC1-exchange-rate component, and as the USD/PLN exchange rate.

We would like to stress the fact that the model including only the principal components outperformed the model including the "domestic" variables. Thus, in order to explain the dynamics of the Polish sCDS we actually do not need any variables representing the economic situation of the country. What drives the dynamics of this risk indicator is the risk perception of other European countries, as well as the risk of American economy.

3. Impact of the Announcements from the American Market

The literature on the effect of macro news on returns and volatility of different financial instruments is huge and includes surveys concerning bond market (see e.g. Ederington, Lee, 1993), foreign exchange market (e.g. Andersen, Bollerslev, 1998) and equity market (e.g. Będowska-Sójka, 2011). Longstaff et al. (2005) confirm the impact of macroeconomic measures of bonds liquidity on CDS spreads. We examine to what extent are sCDS sensitive to macro news announcements and information flow to the market. Therefore, we use seven macro releases commonly used in the literature of macro news announcements effect (e.g. Almeida et al., 1998; Będowska-Sójka, 2011). These are: industrial production, retail sales, consumer confidence, durable goods order, unemployment rate, producer price index, new home sales and purchasing manager index. These announcements are aggregated into indicator variable (DV) taking value of 1 if at least one release occur within the day and zero otherwise. The data considering macro announcements are from www.bankier.pl.

As a measure of intensity of unobservable information arrival we use trading volume of WIG index (Lamoureux, Lastrapes, 1990). We assume that information arrival may influence the sCDS spreads. However, we are aware of the fact that in some cases trading volume cannot be an accurate proxy for information arrival. It refers to the liquidity motivated trading activities, heterogeneity among traders' expectations and beliefs etc. (see Kalev et al., 2004). By incorporating lagged trading volume into the conditional volatility equation of the FIGARCH(1,*d*,1) model we examine if the rate of news arrivals significantly influence the conditional volatility.

We model sCDS return series, r_t, with AR(1)-FIGARCH (1,*d*,1) process (see Appendix 2). We introduce into the conditional variance equations indicator variable standing for aggregated macro announcements. Dummy variable, DV_t, has a value of 1 at the day of macro announcements and zero otherwise. This variable is responsible for the impact of the macro releases on the conditional volatility. If there is any influence of these macro releases, the estimated parameter should be significant. In another model we introduce the lagged volume, VOL_{t-1}, into the conditional variance equation in order to account for undefined information. The significance of the parameter standing by the volume variable would suggest that information inflow affect sCDS volatility. The FIGARCH model is chosen from the GARCH class models – the choice is based on information criteria and the value of logarithm of likelihood function.

The results of model estimation are shown in Table 7. The impact of macro news is not significant. However, the lagged stock index volume variable appeared to be significant. It suggests that overall activity driven at least by incoming information or the rate of news arrivals are influencing sCDS premia's volatility significantly.

Parameters are stable across different specifications. When included in the equation, the lagged volume causes substantial reduction in the value of the constants' parameter in the conditional variance equation. However, both α and β do not change substantially. Thus sCDS returns are not sensitive to the examined public macro announcements, but they are to some extent influenced by unspecified information.

Conclusions

In the paper we analyzed dynamics of Polish sovereign Credit Default Swaps and checked its reaction to the changes of variables reflecting economic situation of the country, as well as the ones connected with economic situation in the world financial markets. In order not to replicate our previous findings, as well as not to lose too much information, we did not consider the actual fundamentals (of monthly or quarterly frequency), but concentrated on the variables from financial markets, such as bonds, exchange rates and stock indices. We compared the models that included the "domestic" variables with the ones including the analogous variables from neighborhood countries.

We found that although the variables reflecting the economic situation of the country play a significant role in explaining the dynamics of the sCDS premia, the model that take into account only the environment variables is capable to explain the dynamics of the premia even better. Both the exchange rates and bond spreads have a strong explanatory power in explaining the sCDS premia. We find also that the impact of important macro news from the American economy on the dynamics of the sCDS premia is insignificant. However, we show that the impact of information inflow proxied by trading volume is strong.

Taking into account the findings presented in the paper, we doubt whether the premium of the Polish Sovereign Credit Default Swaps should be treated as the risk indicator of the Polish economy. Moreover, the results of the research suggest that the links among some segments of world financial markets can be stronger than the links among these segments within one country.

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Sytuacja gospodarcza kraju, czy oczekiwania? Co decyduje o dynamice polskich kontraktów CDS?

Z a r y s t r e ś c i. W artykule dokonano analizy dynamiki kontraktów CDS (Credit Default Swap – instrumentów zamiany ryzyka kredytowego) wystawianych na polskie euroobligacje. Badanie dotyczy okresu 2008-2013. Celem badania jest określenie, czy na dynamikę kontraktów wpływ mają wydarzenia międzynarodowe, czy też krajowe, a w rezultacie, czy spread kontraktów, interpretowany jako wskaźnik ryzyka danego kraju, faktycznie to ryzyko odzwierciedla. Na podstawie uzyskanych wyników można stwierdzić, że do opisu dynamiki i zmienności kontraktów CDS wystarczy model ze zmiennymi reprezentującymi ryzyko krajów sąsiadujących, nie uwzględniający wielkości związanych z jego gospodarką.

S ł o w a k l u c z o w e: CDS, obligacje, indeksy giełdowe, kurs walutowy, zmienność, przenoszenie zmienności, analiza zdarzeń.

Appendix 1 – Tables

Table 1. Estimates of the unrestricted VAR model for Polish sCDS, bond spread, exchange rate, WIG and its volume

Dependent variable	Explanatory variable	Coeff.	Standard error
CDS			
	CDS(–1)	0.0011	0.0359
	WIG(–1)	–0.3740	0.1062
	VOL(–1)	–0.0029	0.0022
	bond(–1)	0.2365	0.0571
	plnusd(–1)	–0.0004	0.1110
	const	–0.0006	0.0012
WIG			
	CDS(–1)	0.0078	0.0121
	WIG(–1)	0.0790	0.0358
	VOL(–1)	–0.0014	0.0007
	bond(–1)	–0.0408	0.0193
	plnusd(–1)	–0.0131	0.0375
	const	0.0004	0.0004
Volume (WIG)			
	CDS(–1)	0.3037	0.4480
	WIG(–1)	0.8220	1.3266
	VOL(–1)	–0.3923	0.0272
	bond(–1)	0.1560	0.7137
	plnusd(–1)	–2.8653	1.3867
	const	0.0004	0.0146
bond spread			
	CDS(–1)	–0.0060	0.0220
	WIG(–1)	0.1329	0.0651
	VOL(–1)	–0.0010	0.0013
	bond(–1)	0.0910	0.0350
	plnusd(–1)	0.0277	0.0681
	const	–0.0003	0.0007
PLN/USD			
	CDS(–1)	–0.0240	0.0108
	WIG(–1)	0.1525	0.0319
	VOL(–1)	0.0007	0.0007
	bond(–1)	–0.0669	0.0172
	plnusd(–1)	–0.2078	0.0333
	const	–0.0003	0.0004

Note: the bolded parameters are statistically significant at α=0.05. CDS(–1) denotes the lagged change of CDS, WIG(–1) – lagged change of WIG, VOL(–1) – lagged volume, bond(–1) – lagged change of bond, plnusd(–1) – laggech change of exchange rate, while const – a constant.

Table 2. Estimates of the DCC–Engle model – univariate GARCH models and conditional correlations

Variable	Coefficient	Std.Error
CDS		
ω x 10^4	0.3946	0.1872
α	0.1082	0.0301
β	0.8680	0.0304
WIG		
ω x 10^4	0.0103	0.0052
α	0.0674	0.0128
β	0.9259	0.0130
Volume		
ω	*0.0098*	*0.0114*
α	*0.0536*	*0.0362*
β	0.9062	0.0808
Bond spread		
ω x 10^4	0.1408	0.0582
α	0.0885	0.0217
β	0.8878	0.0254
Exchange rate		
ω x 10^4	0.0217	0.0103
α	0.0705	0.0208
β	0.9123	0.0230
Correlations		
ρ_(CDS, WIG)	–0.4638	0.0350
ρ_(CDS, volume)	*–0.0081*	*0.0449*
ρ_(CDS, bond)	0.4456	0.0359
ρ_(CDS, exR)	–0.4216	0.0364
ρ_(WIG, volume)	*0.0145*	*0.0440*
ρ_(WIG, bond)	–0.4154	0.0363
ρ_(WIG, exR)	0.3613	0.0388
ρ_(volume, bond)	*0.0036*	*0.0415*
ρ_(volume, exR)	*0.0031*	*0.0437*
ρ_(bond, exR)	–0.3329	0.0377
a	0.0160	0.0040
b	0.9554	0.0154
df	11.1557	1.1568

Note: the bolded parameters are statistically significant at α=0.05. All the parameters named according to Formulas (3) and (4) in Appendix 2.

Table 3. Principal Component Analysis – bond spread. Components loadings and explanatory power of the variance of the system

	PC1	PC2	PC3	PC4	PC5	PC6
HU.spread	0.3204	–0.4507	–0.7563	0.0408	–0.3473	–0.0056
ESP.spread	0.5082	–0.1212	–0.0171	0.1036	0.6836	–0.4987
FR.spread	0.5409	–0.1180	0.2363	0.1014	0.1367	0.7802
UK.spread	0.1981	0.7156	–0.2518	0.6077	–0.1260	–0.0097
SVE.spread	0.3007	0.5036	–0.2166	–0.7796	0.0033	0.0341
FI.spread	0.4657	–0.0503	0.5114	–0.0140	–0.6144	–0.3759
Standard deviation	1.5202	1.045	0.9043	0.8842	0.77257	0.63295
Proportion of Variance	0.3852	0.182	0.1363	0.1303	0.09948	0.06677
Cumulative Proportion	0.3852	0.5672	0.7035	0.8337	0.93323	1

Note: first component explained only about 40% of the system variance. HU.spread denotes spread of Hungarian bonds, ESP – the Spanish ones, FR– the French ones, UK – the British ones, SVE – the Swedish ones, while FI – the Finnish ones.

Table 4. Principal Component Analysis – exchange rates. Component loadings and explanatory power of the variance of the system

	PC1	PC2	PC3	PC4	PC5
eurpln	0.5531	–0.0157	0.1965	–0.1719	–0.7910
gbppln	0.5140	–0.1654	0.3073	–0.5496	0.5585
hufpln	0.2960	0.7208	–0.5928	–0.1847	0.0856
sekpln	0.4946	0.1695	0.2425	0.7835	0.2324
usdpln	0.3124	–0.6512	–0.6758	0.1432	0.0324
Standard deviation	1.6563	0.985	0.8267	0.6385	0.44174
Proportion of Variance	0.5487	0.1941	0.1367	0.08154	0.03903
Cumulative Proportion	0.5487	0.7428	0.8794	0.96097	1

Note: first component explained almost 55% of the system variance. The eurpln denotes the exchange rate of euro, gbppln – of British pound, hufpln – of Forint, sekpln – of Sweden, while usdpln – the American one.

Table 5. Principal Component Analysis – stock exchange indices. Component loadings and explanatory power of the variance of the system

	PC1	PC2	PC3	PC4
BUX	–0.4351	0.8218	–0.3677	0.0113
CAC	–0.5448	–0.0776	0.4497	–0.7035
DAX	–0.5455	–0.1052	0.4323	0.7103
S&P	–0.4651	–0.5546	–0.6897	–0.0196
Standard deviation	1.737	0.7495	0.6061	0.2347
Proportion of Variance	0.754	0.1404	0.0918	0.0138
Cumulative Proportion	0.754	0.8944	0.9862	1

Note: first component explained over than 75% of the system variance. BUX denotes the Hungarian stock exchange index, CAC – the French one, DAX – the German one, while S&P – the American Standard and Poor's.

Table 6. Estimates of ARMA–GARCH Models of the dynamics of Polish sCDS spread (model 0–4) .

	model 0		model 1		model 2		model 3	
Variable	Coeff.	Std.Error	Coeff.	Std.Error	Coeff.	Std.Error	Coeff.	Std.Error
CondME								
$PC_{bond, t}$			0.116	0.009			0.095	0.010
$PC_{ex, t-1}$			0.177	0.069			0.253	0.080
$PC_{in, t-1}$			0.148	0.037			0.159	0.036
$Bond_t$					0.503	0.056	0.198	0.045
WIG_{t-1}					–0.387	0.072		
ER_{t-1}							0.176	0.083
CVarEq								
$(PC_{ex, t-1})^2$			0.367	0.097				
Vol_{t-1}					0.000	0.001		
$(WIG_{t-1})^2$					0.390	0.133	0.486	0.123
$(Bond_{t-1})^2$					–0.001	0.022		
α	0.110	0.002	0.100	0.022	0.090	0.022	0.088	0.020
β	0.842	0.030	0.841	0.030	0.836	0.033	0.828	0.029
DF	4.230	0.388	4.218	0.366	4.258	0.418	4.332	0.402
ω	0.001		0.002		0.002		0.002	
LL	2301		2460		2403		2481	
LL ratio (mod. 0)			0.000		0.000		0.000	
LL ratio (mod. 3)	0.000		0.000		0.000			

Note: $PC_{bond,t}$ stands for first principal component in PCA for bond spreads. $PC_{ex, t-1}$ for exchange rates with lagged values, and $PC_{in, t-1}$ for stock indices with lagged values. $Bond_t$ stands for domestic bond spread changes, WIG_{t-1} is lagged value of WIG returns, ER_{t-1} describes lagged returns of USD/PLN exchange rate, and Vol_{t-1} is lagged value of trading volume of WIG index. Based upon the LL–ratio test we conclude that each of the models: 1, 2, 3 outperform the Model 0, while Model 3 outperforms all of the models: 0, 1 and 2. The bolded parameters are statistically significant at α=0.05.

Table 7. Estimates of Model 4: AR(1)–FIGARCH(1,*d*,1) model of the dynamics of Polish sCDS spread with macro news and trading volume variables

	Coeff.	*Std.err.*	*Coeff.*	*Std.err.*	*Coeff.*	*Std.err.*
AR(1)	0.1017	0.0315	0.1000	0.0315	0.0979	0.0333
$\omega*10^4$	306.8671	51.9121	289.8801	36.5562	262.7081	22.7071
DV_t			–0.0001	0.0001		
$Vol_{t-1}*10^4$					2.4900	0.0359
d	0.7570	0.0452	0.7510	0.0461	0.7584	0.0444
α	0.0656	0.1051	0.0629	0.1020	0.0589	0.1104
β	0.7144	0.0587	0.7100	0.0599	0.7349	0.0548
df	3.2024	0.2381	3.2201	0.2436	3.1553	0.2245
LL	2311.7111		2312.3212		2313.1121	
LL ratio test			0.27		0.09	

Note: Vol_{t-1} is lagged value of trading volume of WIG index. DV_t is an indicator variable standing for aggregated macro announcements The bolded parameters are statistically significant at α=0.05.

Appendix 2 – The models

ARMA–GARCH MODEL (Bollerslev, 1986) with explanatory variables.
Let us denote by y_t the value of the process at time *t*. The following model:

$$
\begin{aligned}
r_t &= \sum_{i=1}^{m} a_i r_{t-i} + \sum_{j=1}^{n} b_j y_{t-j} + y_t + \sum_{k=1}^{t} z_k, \\
y_t &= \sigma_t \varepsilon_t, \\
\sigma_t^2 &= \omega + \sum_{i=1}^{p} \alpha_i y_{t-i}^2 + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^2 + \sum_{k=1}^{r} w_k,
\end{aligned} \tag{1}
$$

is called an ARMA–GARCH model with explanatory variables z_i and w_j. We assume that ε_t is an iid process of mean 0 and unit variance. Moreover, $\omega > 0, \alpha_i \geq 0, \beta_i \geq 0$.

In Section 3 we use AR(1)–FIGARCH(1,*d*,1) model with specification given by Chung (1999):

$$
\begin{aligned}
&r_t = \varphi_1 r_{t-1} + y_t, \qquad y_t = \sigma_t \varepsilon_t, \\
&\alpha(L)(1-L)^d (y_t^2 - \sigma_i^2) = [1 - \beta(L)](y_t^2 - \sigma_{i,t}^2),
\end{aligned} \tag{2}
$$

where: $\mathrm{A}(L) = 1 - \sum_{i=1}^{q} \alpha_i L^i, \mathrm{B}(L) = 1 - \sum_{i=1}^{p} \beta_i L^i$, a $0 \leq d \leq 1$ is fractionally integrated parameter.

THE DCC MODEL (Engle, 2002).

Let us denote by y_t the value of the process at time *t*. Let us assume also that:

$$
\begin{aligned}
&y_t \mid \mathrm{F}_{t-1} \sim N(\mathbf{0}, \mathbf{H}_t), \\
&\mathbf{H}_t = \mathbf{D}_t \mathbf{R}_t \mathbf{D}_t,
\end{aligned} \tag{3}
$$

where:

$$
\begin{aligned}
&\mathbf{D}_t = diag(\sqrt{h_{11,t}}, \ldots, \sqrt{h_{kk,t}}), \\
&h_{ii,t} = \varpi_{i,t} + \sum_{j=1}^{q} \alpha_{ij} y_{i,t-j}^2 + \sum_{j=1}^{p} \beta_{ij} h_{ii,t-j}, \; i = 1, \ldots, k, \\
&R_t = (diag(\mathbf{Q}_t)^{-1/2} \mathbf{Q}_t (diag(\mathbf{Q}_t))^{-1/2}, \\
&\mathbf{Q}_t = \left(1 - \sum_{m=1}^{M} a_m - \sum_{n=1}^{N} b_n\right) \overline{\mathbf{Q}} + \sum_{m=1}^{M} a_m \mathbf{u}_{t-m} \mathbf{u}_{t-m}' + \sum_{n=1}^{N} b_n \mathbf{Q}_{t-n}.
\end{aligned} \tag{4}
$$

The vectors $\mathbf{u}_t$ are k–dimensional and $u_{it} = y_{i,t} / \sqrt{h_{ii,t}}$ .The k–dimensional matrix $\overline{\mathbf{Q}}$ is the unconditional covariance matrix of $\mathbf{u}_t$. It is also assumed that the scalars a_m and b_n are non–negative and $\sum_{m=1}^{M} a_m + \sum_{n=1}^{N} b_n < 1$.

In our study we estimated the model with Student distribution, i.e. we assumed that:

$$y_t \mid \mathsf{F}_{t-1} \sim t(\mathbf{0}, \mathbf{H}_t, \nu),$$

where ν denotes degrees of freedom. The value of this parameter is established through estimation. When $\nu > 2$, then $\mathbf{H}_t$ exists and is interpretable as a conditional variance matrix.

The model was estimated using the two–step procedure. First, the $\overline{\mathbf{Q}}$ was estimated as the unconditional correlation matrix of $\mathbf{u}_t$. Then, the parameters a and b were estimated by Gaussian quasi maximum likelihood. Bollerslev and Wooldridge (1992) showed that even in the case when data generating process is not conditionally Gaussian, we can obtain a consistent estimator using the Gaussian quasi maximum likelihood. For more details considering estimation in G@RCH package see eg. (Laurent et al., 2012).