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The Impact of the World Financial Crisis on the Polish Interbank Market: A Swap Spread Approach

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Abstract

The swap spread is defined as the difference between the fixed rate of an interest rate swap and the yield of the treasury with the same maturity. The swap spread is usually interpreted as the effective proxy of bank liquidity and the credit spread indicator. The interpretation is very similar to the LIBOR-OIS spread and in the context of Polish interbank market – WIBOR-OIS. However, WIBOR-OIS is less reliable during the crisis of confidence because of lack of interbank operation with the maturity longer than 1 month. Swap spreads base on two liquid instruments, thus they are free of this defect.
The main goal of this paper is to assess how Polish swap spreads and their conditional variance reacted to important events connected with the subprime crisis and crisis of confidence in the Polish interbank market.

Keywords: credit risk, interest rates, multidimensional parametric models, semiparametric models, swap spread

JEL Classification: C14, E52

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1 Introduction

First problems in the world interbank markets could be observed as early as in 2007. As a result of the mortgage loans crisis in the USA and following news about financial problems of some of the leading banks we could observe signs of confidence crisis among commercial banks. On 9th August 2007 BNP Paribas suspended withdrawals from three funds investing in the bonds secured by subprime mortgages, because turbulences on the financial markets made it impossible to price their assets. This date is considered to be an official date of the beginning of the crisis. In spite of rapid reaction of FED and central banks of Canada, Australia and Japan (commercial banks in those countries were provided with total of 300bln USD) the crisis of confidence hit banking sectors in the countries in which banks were most engaged in subprime mortgage market. It was later transmitted to the euro zone due to diminished inflow of capital and decreased lending. In the first phase of the crisis the effects of international turbulences were almost imperceptible in Poland. They were noticeable only in capital market. The situation in Polish bank sector was much better than in the USA and the euro zone. Polish banks did not possess so called "toxic assets" (assets connected with American mortgage market, with big counterparty risk). Total value of their deposits in foreign banks was small. Moreover, many of the deposits were liquidated in third and fourth quarter of 2008 (see National Bank of Poland, 2009 for more details). The crisis of confidence was transmitted to Poland at the end of fourth quarter of 2008, after the bankruptcy of Lehman Brothers on 15th September 2008. Banks drastically decreased credit limits for interbank transactions. Considerable turnover remained only in the overnight deposit market. Long-term WIBOR rates that were quoted in the fixing in ACI-Polska by banks-money market dealers, were not confirmed by any transactions. Commercial banks aimed at maintaining significant liquidity surpluses on their current accounts. Since the reserves above the required ones, kept in the NBP, are not remunerated, banks placed the accumulated excess funds in the central bank using standing deposit facility. In October 2008 the National Bank of Poland introduced the so called Confidence Pact in order to provide banks with zloty and foreign currency funds. The possibility to obtain zloty liquidity was extended; the central bank introduced repo transactions of maturity up to 3 months, reduced the haircut of the security for the marginal lending facility and expanded the list of assets which may have acted as a security for the marginal lending facility with the NBP. The Confidence Pact allowed commercial banks to obtain funds in Polish zloty and foreign currencies in the central bank if they were unable to obtain them from other banks, but unfortunately, it did not stimulate the reconstruction of the confidence (see Kliber, Płuciennik, 2011 for more details). The crisis of confidence ended was coming to an end was completing in the first half of 2010. The end of the subprime crisis coincided with first signals of fiscal crisis in Greece.

During the turbulence in the world markets very important issue is the assessment of the situation of the bank sector. Very popular measure of it is LIBOR-OIS spread, called the “barometer of fears of bank insolvency” by Alan Greenspan. Many authors interpreted it as a measure of liquidity and credit risk in the interbank market (see Sengupta, Yu, 2009, Thornton, 2009). Considering such kind of measure in the context of Poland during the confidence crisis had a major flaw: during the crisis of confidence Polish banks did not lend money to other banks for a period longer than 1 month. Therefore we are not able to assess how accurately the WIBOR rate reflects the cost of the money in the interbank market (the most often used LIBOR-OIS spread bases on the 3-month rates). Similar but less popular measure of bank sector condition is the swap spread. It is determined on the basis of interest rate swaps and treasury bonds. Both instruments are liquid in Poland, so the swap spread is more reliable than the WIBOR-OIS. Average daily turnover of interest rate swaps except OIS contracts was 580 million USD in April 2007 and 426 million USD in April 2010 (see National Bank of Poland, 2010). If we take into account the average face value of the swaps it means that in the considered period there was conducted average about 10 swaps per day.

Our goal is to verify how the swap spreads and their conditional variance can explain changes in the Polish interbank market, which occurred after transmission of the world financial crisis to Poland. We are going to show that the Polish swap spread is a useful tool, helpful in assessing the condition of interbank market.

Polish swap spread was analyzed only once (in cyclical National Bank of Poland Financial Stability Report starting from October 2008) and only its levels were studied. The conditional variance of swap spread contains additional information about the situation in the market. It can be interpreted as a measure of uncertainly of future liquidity and credit risk. Therefore in this article we additionally determine the conditional variance of the swap spreads and we assess its relation with important market signals.

2 The swap spread

The swap spread is defined as a difference between the swap interest rate and the government interest rate with the same maturity, i.e.

$$ss^c_{i,t} = s^c_{i,t} - g^c_{i,t}, \tag{1}$$

where $s^c_{i,t}$ is the i-period swap rate for c-currency at time t, and $g^c_{i,t}$ is the i-period government rate in the c-market at time t.

To determine the swap spreads on-the-run government treasuries are usually used. The maturity of applied interest rate swaps and treasuries is long. Many authors (e.g. Grinblatt, 2001, Huang at al., 2003) analyzed the swap spread determined on the basis of 10-years rates. The swap spread measures how counterparties divide swap surplus. Therefore it has various interpretations, which we can find in many literature items. Swap spread can be understood as an effective proxy of banking liquidity. This interpretation is proposed by Grinblatt (2001). Huang and Nefci (2003) present additional swap spread interpretation: A proxy of AA- credit spread; and point out that the swaps spread is affected by government efforts to manage national debt.

Lang et al. (1998) use the average swap spreads to analyze the changes of the counterparty risk in swaps. Fang and Muljono (2003) investigate the swap spread for Australian dollar and find that they mostly represent a credit risk premium. Very interesting result was obtained by Duffie and Singleton (1997). On the basis of the VAR regression they show that both corporate credit risk and liquidity affect the swap spread. They conclude that the "liquidity effects are short-lived", "credit effects are weak initially" but "increase in impotence over the longer horizon". Similar results are obtained by Huang at al. (2008). In addition to credit and liquidity premium, other economic determinants of swap spreads are considered. Suhonen (1998), In et al. (2003), Lekkos and Milas (2001, 2004) identified the positive relation between the swap spread and the slope of the yield curve and interest rate volatility. Huang and Chen (2007) and Ito (2010) noted that swap spread depends also on monetary policy regimes.

Huang and Chen (2007) show that the slope of the term structure characterize the time varying nature of swap spread variance and that the liquidity premium is the only contributor to the 2-year swap spread variance in monetary tightening cycles. Similar results were obtained by Lee and Hong (2009), which analyzed the swap spread for Hong-Kong, China and USA.

Polish interest rate swap market is relatively young. Market standard for interest rate swap was not introduced before 1999. Until 1999 the Polish zloty interest rate swaps were being entered into very seldom. After hyperinflation between 1989 and 1991 connected with political system transformation, inflation in Poland was falling incessantly since 1992. Systematic decrease of inflation rate caused the steady decline of market interest rates. First two raises of policy interest rates by National Bank of Poland on 23rd September 1999 and 18th November 1999, and change of long-term inflation trend led to the Polish zloty IRS being entered into much more often. Since then the interest rate swap market in Poland is developing very rapidly. The principal participants in the interest rate swap market are commercial banks and brokerage firms. Private companies are also significant part of the market. In 1999 Polish interest rate swaps appeared in London interbank market, after acceptation of the payments in Polish zloty in April 1999.

3 Data

In the following section we discuss basic properties of Polish swap spreads with maturities 1, 2, and 5 years from the period 2nd January 2006 to 30th June 2010 and the 1- and 3-month WIBOR-OIS spreads from the same period. Considered period includes the subprime crisis and first events connected with fiscal crisis in Greece.

Swap spreads are being calculated as the difference between the Polish swap rates and the government bond indices with the same maturities. The choice of the maturities of swap spreads is determined by the liquidity of the swaps (the most

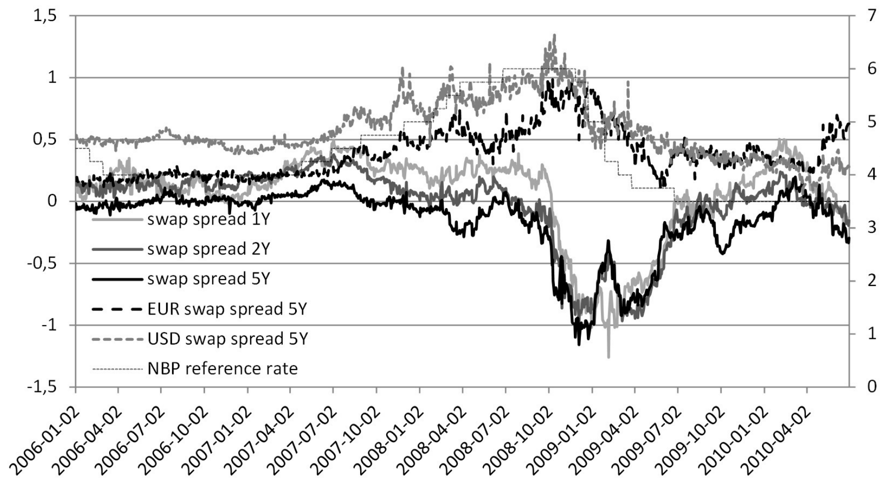
liquid interest rate swaps are those with short maturities). WIBOR-OIS spreads are defined as a difference between corresponding WIBOR rates and average OIS rates. 3-month LIBOR-OIS spreads are the most popular (see In at al., 2008, Soultanaeva and Strömqvist, 2009, Poskitt, 2011). 3-month WIBOR-OIS is used in semi-annual National Bank of Poland Financial Stability Report. Together with the development of the crisis of confidence we observe changes in the unsecured interbank loan market. Loans with maturity up to one week comprised 95% of total turnover in 2007 and almost 99% in 2010. Loans with maturity longer than one month were disappearing. As a result, it is impossible to verify how the WIBOR 3M reflects the real money cost in the interbank market (in other interbank markets we can observe the same problem). Therefore we consider 1-month WIBOR-OIS spread as well. All data comes from Thomson Reuters Datastream.
Since both swap spreads and WIBOR-OIS spreads series are not covariance stationary, we determine the first difference series. The covariance stationarity of the first growth series is confirmed by three tests for stationarity and four tests for unit root. Their results (table 1) show that the swap spread growth series and WIBOR-OIS growth series are stationary. It allows us to model the swap spread growth with the vector-autoregressive models.

Table 1: The tests for stationarity ($I(0)$) and unit root ($I(1)$)

Series	$I(0)$			$I(1)$			
	RL (1998)	KPSS (1992)	HML (2008)	ADF (1984)	PP (1988)	DF-GLS (1996)	P (1996)
Swap spread 1Y	-1.7275	0.042	-0.1844	-46.442	-46.442	-45.848	0.01553
	(0.958)	(>0.5)	(0.573)	(<0.01)	(<0.01)	(<0.01)	(<0.01)
Swap spread 2Y	-0.6575	0.03519	-0.4071	-47.076	-47.113	-46.053	0.01553
	(0.745)	(>0.5)	(0.658)	(<0.01)	(<0.01)	(<0.01)	(<0.01)
Swap spread 5Y	-0.4363	0.03519	0.79661	-42.128	-42.161	-39.293	0.02066
	(0.669)	(>0.5)	(0.213)	(<0.01)	(<0.01)	(<0.01)	(<0.01)
1M WIBOR-OIS	-3.3987	0.028387	-0.2461	-18.243	-47.988	-18.235	0.93152
	(1)	(>0.5)	(0.597)	(<0.01)	(<0.01)	(<0.01)	(<0.01)
3M WIBOR-OIS	-2.1015	0.079105	-1.7162	-10.586	-39.447	-23.062	0.045636
	(0.982)	(>0.5)	(0.957)	(<0.01)	(<0.01)	(<0.01)	(<0.01)

The former test was introduced by Robinson and Lobato (1998). We apply also Kwiatkowski et al. (1992) test for maximum lag equal to $4(T/100)^{0.25}$, similarly as Schwert (2002). The last test of $I(0)$ is based upon the long-range autocovariances and is called HML (named after authors: Harris, McCabe and Leybourne 2008). The HML statistic depends on two parameters, a truncation parameter c where $k = cT^{1/2}$ is the lowest-order lag, and L, where $l = LT^{12/25}$ is the bandwidth truncation of the variance parameter. We decided to choose $c = 1$ and $L = 2/3$, on the basis of

Figure 1: The Polish swap spreads with the one, two and five year maturity and the 5-year swap-spreads for US dollar and euro from 2nd January 2006 to 30th June 2010 (primary axis) and the National Bank of Poland reference rate (secondary axis).



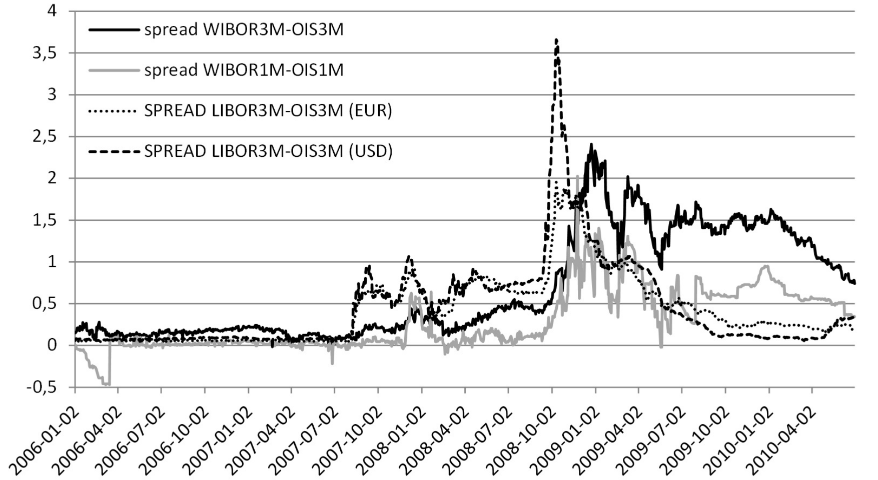
simulation research of Harris, McCabe and Leybourne (2008). For such values the test has both big power and small size.
We used the ADF test (Said and Dickey, 1984) with the maximum lag chosen on the basis of the Hannan-Quinn information criterion, as well as of the PP test (Phillips and Perron, 1988), with the maximum lag equal $4(T/100)^{0,25}$ as in Perron (1988). We also used the modified ADF test (DF-GLS) and the feasible likelihood ratio test – the P test (Elliott, Rothenberg and Stock, 1996). The descriptive statistics of the swap spreads growths and WIBOR-OIS growths are presented in the table 2.

Table 2: The descriptive statistics of the growths of the swap spread with one, two, and five year maturities and growth of 1- and 3-month WIBOR-OIS spreads.

	Mean	Standard deviation	Minimum	Maximum	Skewness	Kurtosis
Swap spread 1Y	-9.41E-5	0.044197	-0.3054	0.3308	0.23327	12.15
Swap spread 2Y	-2.22E-4	0.038656	-0.34	0.4068	0.15217	18.497
Swap spread 5Y	-1.64E-4	0.036789	-0.38	0.3468	-0.26419	20.269
1M WIBOR-OIS	3.05E-4	0.09039	1.8034	50.619	-0.99	1.11
3M WIBOR-OIS	5.22E-4	0.059751	0.45379	17.675	-0.41	0.425

All swap spreads are shown in the figure 1. Until the last quarter of 2006 swap spread with 5-year maturity oscillate near 0, and two others spreads near 0,2%. From the beginning of 2007 to July 2007 they had gently growing trend. While the swap spreads in the USA and euro zone began to increase dynamically from August 2007,

Figure 2: The WIBOR-OIS spreads with 1- and 3-month maturity together with 3-month spreads for euro and US dollar from the period from 2nd January 2006 to 30th June 2010.

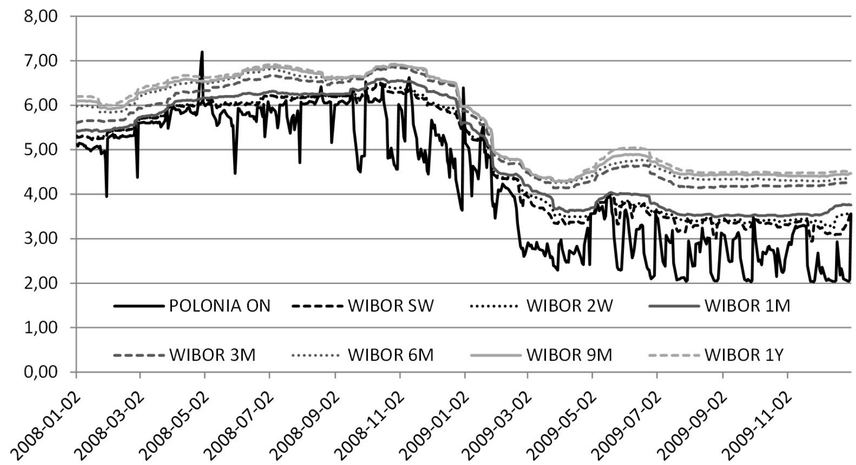


Polish swap spreads began to fall. The interest rates in IRS transactions did not grow, which suggests that the crisis of confidence had not yet transmitted to Poland. Swap spreads began to grow again in the beginning of 2008. The inversion of the trend of the swap spread was the consequence of growing fear of insolvency in the interbank market, which was connected with problems of big commercial banks – Bear Stearns and Northern Rock. (The first one was sold to JP Morgan Chase for 10 USD per share, a price far below its pre-crisis 52-week high of 133.20 USD, and the second one was nationalized by the British Government). At the end of fourth quarter of 2008 we could notice considerable fall of the swap spread, which was a consequence of growing yield of Polish treasuries. The Financial Stability Report of National Bank of Poland from July 2009 adduced three reasons for it:

1. risk aversion related to investing in the markets of the region connected with public finance crisis in Hungary,
2. the expected high bond supply connected, among others, with the risk of an increase in the state budget deficit (dynamics of Polish GDP fall in fourth quarter of 2008) and the need to repurchase maturing treasury securities,
3. rising investor propensity to investment only in highly liquid assets.

The negative value of swap spread is very untypical. Swap spread analysis are based on the assumption that the treasuries are "perfect" assets, particularly counterparty risk free and easily tradable. In the context of fiscal problems of many countries and

Figure 3: POLONIA rate and the WIBOR-OIS rates with maturity from 1 week to 1 year from the period from 2nd January 2008 to 30th December 2009.



the beginning of crisis of confidence in Poland rate of treasuries must include the risk and liquidity premium.
Problem of negative swap spreads occurred also in USA but it concerned only spreads with 10 and 30 years maturity. 10-years spread was negative only during short periods but the 30-years spread remains negative up to the present day. The main reason for the negative value of the swap spreads is perception of long term U.S. Treasuries as not credit risk free (see Van Deventer for more details). After October 2008 Polish treasuries yield began to return to the levels from the growth period and the IRS fixed rate began to rise. It was caused by the rising aversion of the commercial banks to lend for long terms. The interbank transactions concentrated mostly on the market of instruments of maturity shorter than a week. In consequence the POLONIA rate became smaller, and the long-term WIBOR rates bigger. Polish interbank rates in the figure 3 show that the growth of the yield curve slope at the end of 2008 and the beginning of 2009 was huge (the dependencies between the yield curve slope and the swap spreads were explained by Ito (2010)). In February 2009 the NBP decided to leave the liquidity surplus in the market by limiting the supply of NBP bills. In consequence the demand for treasuries grew and the rates of treasuries decreased, which was the reason for the fall of the swap spreads' value. In the following months swap spreads were reaching relatively big positive values. The consequent decrease of the swap spread at the end of considered period was a reliable sign of the end of the confidence crisis. The spread for EUR and USD began to increase, after Greece turned to the EU and IMF for the first bailout package. It led to fall in confidence in the treasuries of emerging markets. Foreign investors sold out Polish bonds, and their yield grew. Before August 2007 WIBOR-OIS spreads oscillated slightly above zero.

The negative shock in 1-month WIBOR-OIS spread is connected with small liquidity of 1-month OIS. After two decreases of basic interest rate by Monetary Policy Council WIBOR 1M fell immediately. Reaction of 1-month OIS rate was strongly delayed. After August 2007 they began to slowly rise while the LIBOR-OIS spreads for USD and EUR rose by more than 50bp. LIBOR-OIS spreads for USD and EUR reacted very rapidly to Lehman Brothers collapse. The reaction of WIBOR-OIS spreads was much weaker, but much more persistent. High level of the spreads lasted up to the beginning of 2010. In contrast to the LIBOR-OIS spreads for USD and EUR, we could not observe any reaction of WIBOR-OIS spreads to nationalization of Northern Rock in February 2008 and Bear Stearns acquisition in March 2008. From the beginning of 2010, when the confidence crisis in Polish interbank market began to expire, WIBOR-OIS spread started to decrease fast and consistently.

4 Models

In the figure 1 we can observe that not only the shape of the swap spreads with various maturities were similar but also periods of their heightened volatility occurred at the same time. Similar conclusion we can draw for WIBOR-OIS spreads, presented in the figure 2. Therefore we decided to use multivariate conditional models. The simpler one is the BEKK model presented by Engle and Kroner (1995), applied in Linton and Perron (2002) iterative procedure. The second one is more advanced cDCC model proposed by Aielli (2009).

The name of the BEKK model came from the first letters of its authors names (Baba, Engle, Kraft and Kroner). In the k-dimensional BEKK(p,q) model the conditional covariance matrix is described by the following equation

$$H_t = (C^*)'C^* + \sum_{i=1}^{p}(A_i^*)'y_{t-i}y_{t-i}'A_i^* + \sum_{i=1}^{p}(G_i^*)'H_{t-i}G_i^*, \tag{2}$$

where C^*, $A_i^*$and G_i^* are $N \times N$, matrices and the C^* is upper triangular matrix, y_t is the residual vector in the moment t. The number of parameters in this model equals $(p+q)N^2+N(N+1)/2$. To reduce this number one can estimate the diagonal BEKK model in which matrices A^* and G^* are diagonal, or the scalar BEKK model in which they are the product of scalar and the identity matrix.

The conditional covariance matrix in the second used model, cDCC(M,N), is described by the following equation

$$H_t = D_t R_t D_t \tag{3}$$

where

$$D_t = diag\left(\sqrt{h_{11,t}}, ..., \sqrt{h_{kk,t}}\right), \tag{4}$$

h_{ii} is described by univariate conditional heteroscedasticity model. Furthermore

$$R_t = (diag(Q_t))^{-1/2}Q_t(diag(Q_t))^{-1/2}, \tag{5}$$

where

$$Q_t = (1 - \sum_{m=1}^{M} \alpha_m + \sum_{n=1}^{N} \beta_n)\bar{Q} + \sum_{m=1}^{M} \alpha_m u^*_{t-m}(u^*_{t-m})' + \sum_{n=1}^{N} \beta_n Q_{t-n}, \tag{6}$$

$u^*_t = P_t u_t$, u_t is the standardized residual vector in time t, $P_t = \text{diag}(\sqrt{q_{11,t}}, ..., \sqrt{q_{kk,t}})$ and $\bar{Q}$ is the unconditional covariance matrix of u_t.
This model is the modification of the DCC by Engle (2002). Aielli (2009) corrected the equation of Q_t to eliminate the problem of inconsistent estimator of unconditional variance of standardized residuals. The covariance stationary holds if

$$\sum_{m=1}^{M} \alpha_m + \sum_{n=1}^{N} \beta_n < 1. \tag{7}$$

We described the linear dependencies in two different ways. First we used the VAR model. The second one is based on the work of Castagnetti (2004). Author showed that although linear dependencies between conditional variance and conditional mean of swap spreads do not exist, there are the nonlinear relations. Therefore Castagnetti (2004) suggested using the semiparametric model to describe the conditional mean of the swap spreads. She assumed that realized $(N \times 1)$ vector of swaps spread growths $\Delta ss^c_t = [\Delta ss^c_{1t}, ..., \Delta ss^c_{Nt}]$ is generated as follows:

$$\Delta ss^c_t = \hat{g}(H_t) + \varepsilon_t, \tag{8}$$

$\varepsilon_t \sim iid(0, H_t)$ and H_t is the conditional variance–covariance matrix. Following Castagnetti (2004) we assume that conditional mean of growth of i-th considered swap spreadΔss^c_{it} depends upon its own conditional variance. Therefore we have

$$\Delta ss^c_{it} = \hat{g}(h_{it}) + \varepsilon_t, \tag{9}$$

where $\varepsilon_t \sim iid(0, h_t)$, and h_{it} is the conditional variance of i-th considered swap spread, and $\hat{g}(h_t)$ is the univariate Nadaraya-Watson estimator and

$$\hat{g}(h_{i,t}) = \frac{\sum_{j=1}^{T} \delta^c_{i,t} K((h_{i,t} - h_{i,j})/\lambda_{i,t}(T))}{\sum_{j=1}^{T} K((h_{i,t} - h_{i,j})/\lambda_{i,t}(T))}, \tag{10}$$

where K is a bounded kernel function, and $\lambda_{i,t}(T) = 1,06 \cdot \sigma(h_{i,t})T^{-1/5}$ is the bandwidth parameter. Application of the semiparametric model is connected with generates an obstacle. In order to estimate $g()$ we need an estimate of H_t, which depends on lagged ε_t, which in turn depends on lagged $g()$. Linton and Perron (2002) propose an algorithm that includes the nonparametric estimates in the convergence criterion. Unfortunately, the convergence of this algorithm is not proved. Therefore, following Castagnetti (2004), we use simple iterative method to estimate the conditional mean.

1. We choose the starting value of conditional variance $h_t^{[0]}$ and conditional mean $\hat{g}^{[0]}$. Our values are obtained by fitting the GARCH-in-mean model for each considered swap spread growth series.

2. For each considered swap spread growth series we obtain $h_t^{[1]}$ on the basis of the residuals from $\hat{g}^{[0]}$, by using the diagonal BEKK model applied to all residual series simultaneously. $\hat{g}^{[1]}$ is obtained by using univariate Nadaraya-Watson estimator.

3. We repeat the algorithm until the difference between values obtained in successive iterations become negligibly small.

This algorithm is labour-consuming, but assumption that there are only linear relations between conditional variance and conditional mean is too restrictive. The problem of existence of nonlinear dependencies between conditional mean and conditional variance was undertaken by Pagan and Ullah (1988), Pagan and Hong (1990), Gennotte and Marsh (1993), Chauvet and Potter (1999), and Lindton and Perron (2002). What is important, Boudoukh at al. (1997) show that the nonlinear relations between the conditional mean and conditional variance exist also for interest rates.

5 Models estimation

In the following section we present the results of VAR-cDCC and SP-BEKK model estimation. The order of the model was chosen on the basis of Akaike Information Criterion. Two tests (table 3) verified positively the conditional heteroskedakticity of swap spread growths with the linear and collinear dependencies filtered out by VAR(1) model. The Engle Sheppard (2001) test applied to the residuals of the VAR(1) model (table 4) rejected the H0 hypothesis of constant conditional correlation. Therefore, we used the DCC-class model to describe residual variance from the VAR model. In order to reduce the number of estimated parameters we applied the Variance Targeting method. In this method the conditional variance matrix of the autoregressive model was replaced by the unconditional variance matrix. Insignificant parameters were removed from the final model. First we tried to use the "in-mean" version of the model, but the model did not identify the linear relation between the swap spread growth and its conditional variance for any considered swap spread. Since the sum of the estimates of α_{ii} and β_{ii} was close to 1, we decide to use the IGARCH model to describe conditional variance of every swap spread growths series. The results of the estimation are presented in the table 5.

Analyzing the parameter estimates of VAR(1)-cDCC(1,1) model we notice existence of linear dependencies between swap spreads growths series. Necessity to use IGARCH model suggests that there is a strong persistence in the conditional variance series. Similar conclusions can be drawn from analysis of the BEKK model

Table 3: The conditional heteroskedasticity test for the swap spread growth residuals from the VAR(1) model

	Engle test(maximum lag = 5)	McLeod-Li test(maximum lag = 5)
Swap spread 1Y	206.18 (0.000)	279.47 (0.000)
Swap spread 2Y	312.52 (0.000)	241.56 (0.000)
Swap spread 5Y	181.84 (0.000)	243.82 (0.000)

Table 4: The Engle and Shephard test applied to the swap spread growth residuals from the VAR(1) model

Lag	Test statistic (p-value)
5	60.245 (0.000)
10	61.737 (0.000)

Table 5: The parameters estimates of the VAR(1)-cDCC(1,1) model fitted to the swap spread growths

Parameter	Estimate	Std. error	t-ratio	p-value
$a_{1,11}$	-0.20253	0.07076	-2.862	0.004
$a_{1,13}$	-0.14419	0.05004	-2.882	0.004
$a_{1,21}$	0.07408	0.02711	2.732	0.006
$a_{1,22}$	-0.26644	0.0473	-5.633	0.000
$a_{1,33}$	-0.16651	0.05372	-3.1	0.002
α_{11}	0.03815	0.009772	3.905	0.000
β_{11}	0.96184	-	-	-
α_{21}	0.04556	0.01181	3.858	0.000
β_{21}	0.93792	-	-	-
α_{31}	0.06208	0.02543	2.441	0.015
β_{31}	0.93792	-	-	-
ρ_{21}	0.59634	-	-	-
ρ_{31}	0.3395	-	-	-
ρ_{32}	0.71064	-	-	-
α_1	0.02084	0.007	2.974	0.003
β_1	0.96061	0.01278	75.18	0.000

Table 6: The estimates of parameters of the SP-BEKK(1,1) model fitted to the swap spread growths

Parameter	Estimate	Std. error	t-ratio	p-value
a_{11}	0.98648	0.001101	895.4	0.000
a_{22}	0.98662	0.0009304	1060	0.000
a_{33}	0.98661	0.001808	545.6	0.000
b_{11}	0.16116	0.006744	23.9	0.000
b_{22}	0.16046	0.005901	27.19	0.000
b_{33}	0.15713	0.01050	14.96	0.000

Table 7: The conditional heteroskedasticity test for the WIBOR-OIS growths residuals from the VAR(1) model

	Engle test(maximum lag = 5)	McLeod-Li test(maximum lag = 5)
1M WIBOR-OIS	217.27 (0.000)	337.1 (0.000)
3M WIBOR-OIS	226.04 (0.000)	183.1 (0.000)

parameters a_{ii} and b_{ii}, of which sum of squares is very close to 1 (in all three cases it is bigger than 0.998). It does not indicate persistence, but it means that autocorrelation in the variance expires very slowly. Furthermore, the sum of estimates of α_1 and β_1 in cDCC model is bigger than 0.98. It means that the effect of shocks in conditional covariance expires very slowly.
The swap spread growths series were also modeled with the SP-BEKK(1,1) model. We chose the multivariate conditional variance model on account easiness of fitting the BEKK model. The estimation algorithm of the DCC class models often fail to convergence, which makes difficult using this model in the iterative procedure. Therefore, similar to Castagnetti (2004) we chose the BEKK model. The estimation results of the SP-BEKK(1,1) (obtained in the 7-iteration) are presented in the table 6.
For the WIBOR-OIS spreads the Engle-Shephard test (table 8) also rejected the H0 hypothesis. Therefore we also modeled the WIBOR-OIS growth series with VAR(1)-cDCC(1,1) model. The results of the estimation are presented in the table 9. In the VAR(1) model fitted to the WIBOR-OIS spread growths all parameters outside the main diagonal of A_i matrices are statistically insignificant. It shows there is no collinear dependence between two spreads. The sum of estimates of α_1 and $\beta_1$in cDCC model smaller than 0.98 suggests that effect of shocks in conditional

Table 8: The Engle and Shephard test applied to the WIBOR-OIS growths residuals from the VAR(1) model

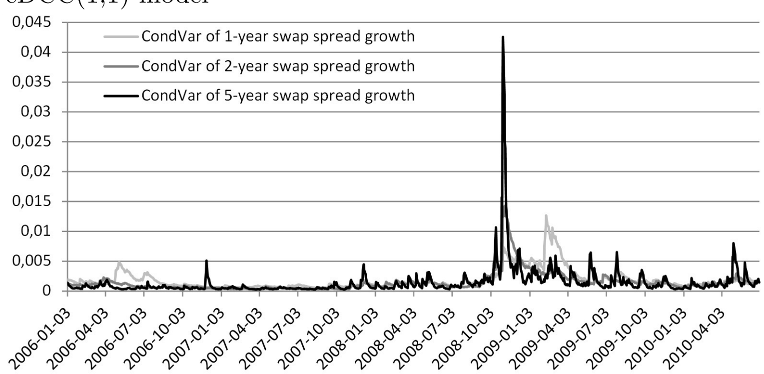
Lag	Test statistic (p-value)
5	15.825 (0.015)
10	59.532 (0.000)

Table 9: The estimates of parameters of the VAR(1)-cDCC(1,1) model fitted to the WIBOR-OIS spread growths

Parameter	Estimate	Std. error	t-ratio	p-value
$a_{1,11}$	-0.31596	0.07954	-3.972	0.000
$a_{2,11}$	-0.17137	0.07394	-2.318	0.021
$a_{1,22}$	-0.33544	0.04679	-7.169	0.000
$a_{2,22}$	-0.14728	0.04652	-3.166	0.002
α_{11}	0.03284	0.01312	2.504	0.012
β_{11}	0.96716	-	-	-
α_{21}	0.07671	0.01442	5.319	0.000
β_{21}	0.92329	-	-	-
ρ_{21}	0.20199	0.041821	4.830	0.000
α_1	0.02074	0.01126	1.842	0.066
β_1	0.86087	0.05619	15.32	0.000

covariance expires quite fast. In the figure 4 and 5 we present the conditional variance of the swap spread growths obtained by using VAR(1)-cDCC(1,1) and SP-BEKK(1,1) models respectively. Some differences were observed in the conditional variance shapes obtained by using the two models. However, in both cases we observed that conditional variance series reacted with similar power to the same impulses from the market. The short-term growth of conditional variance of the 5Y spread at the end of 2007 and 2008 was connected with reporting period and efforts the commercial banks make to demonstrate their good liquidity positions.

Figure 4: Conditional variance of the swap spread growths obtained from the VAR(1)-cDCC(1,1) model



The conditional variance of all swap spreads increased at the beginning of 2008. In this period the Northern Rock was nationalized and the Bear Stearns was taken over

Figure 5: Conditional variance of the swap spread growths obtained from the SP-BEKK(1,1) model.

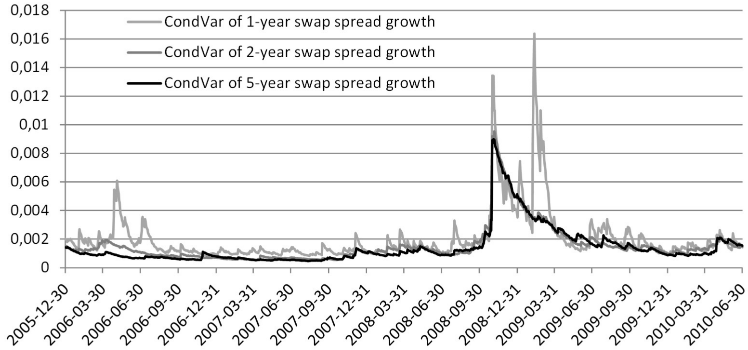
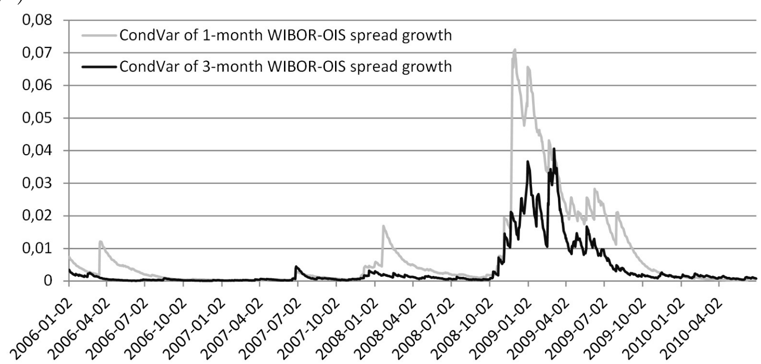


Figure 6: The WIBOR-OIS growths conditional variance obtained from the VAR(1)-cDCC(1,1) model.



by JP Morgan. It caused decrease of confidence in the interbank market; gaining funds in the interbank market became more difficult. The Lehman Brothers collapse did not have significant influence on the swap spread variance. Only small growth of the 5Y swap variance was observed.

Bigger shock in the conditional variance of 2Y and 5Y swap spread happened after introducing the "Confidence Pact" by National Bank of Poland on 4th October 2008. The biggest jump in the conditional variance of all swap spreads was observed in October 2008, after National Bank of Poland decided to stop announcing the supply of the bills and instead to sell them in amounts covering the total demand. Big shock in the conditional variance of the 1Y swap spread was observed at the end of February 2009, after the strong limitations were put on the supply of the National Bank of Poland bills (no reaction of the conditional variance of other spreads was observed).

In the following months the swap spread variance had decreasing tendency. The last shock in the analyzed period was observed in April 2010 when Greece turned to the EU and International Monetary Fund for the first bailout package. What is important, the reaction of market signals is always immediate and persistent. Afonso, Strauch (2004) proved that immediate reaction to fiscal policy impulses is characteristic also for euro swap spreads. Authors proved that the reaction was not persistent. Goldbach and Fahrholz (2010) showed that conditional variance of the swap spread immediately reacted on market impulses but parameters of GARCH-type model suggested that the effect of shocks in conditional variance was transitory. Similar conclusions can be drawn from the analysis of parameters estimates from the BEKK model obtained by Castagnetti (2004). It shows that persistence of reaction to shocks is characteristic feature only for Polish swap spread. The conditional variance of WIBOR-OIS spreads (figure 6) reacts at the end of 2007. We observe two shocks of 1-month WIBOR-OIS spread connected with small liquidity of 1-month OIS at the end of the first quarter of 2006 and the beginning of first quarter of 2008. After Lehman Brothers collapse the conditional variance of WIBOR-OIS spreads began to increase rapidly. We observe strong reaction of the conditional variance of 3-month spread on the limitations put on the supply of the National Bank of Poland bills. The conditional variance of WIBOR-OIS spreads did not react to Greece turning to the EU and IMF for first bailout package but we can observe weak reaction of 3-month WIBOR-OIS to Northern Rock nationalization and Bear Stearns acquisition. The reaction of 1-month WIBOR-OIS to this two events is not observable.

6 Conclusions

Our research shows that Polish swap spreads and its conditional variance react to the market signals. The swap spreads react to both the changing in the liquidity situation and the growing fear in the interbank market. Unfortunately, relation between the supply and the demand for Polish treasury in considered period was changing. Fiscal problems of one European country causes decline of confidence in the treasuries of emerging countries, and in consequence increase of their yield, even when their public finances are in good condition. In considered period we observe two big growths of Polish treasury yield caused by decreasing demand for them: first in September 2008 after the fiscal crisis hit Hungary, second after Greece turned to the EU and IMF for the first bailout package. Therefore, if we analyze Polish swap spreads we must take into account the changes in the treasury yields and their causes. For this reason Polish swap spreads are not as easy to interpret as WIBOR-OIS spreads. On the other hand, the conditional variance of Polish swap spread is susceptible to events influencing the liquidity situation and the credit risk. Considering that the swap spread bases on liquid instruments, we can conclude that the Polish swap spreads and their conditional variance in particular is a helpful tool in assessing the state of interbank market. Very interesting research problem is defining determinants of swap spreads, such as liquidity premium, default risk and slope of yield curve and volatility. Huang and Chen (2007) and Ito (2010) decomposed the swap spreads for USD. Unfortunately, the market of Polish bank CDS is still forming, thus CDS rates in Poland are not published anywhere; it is impossible to decompose the swap spread to aforementioned factors.

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