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The Structural Stability of a One-Day Risk Premium in View of the Recent Financial Crisis

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The aim of this research is to analyze a short-term risk premium in Poland between 2005 and 2015. In particular one-day periods are considered. It is studies whether the same GARCH type model can be applied for the whole period, or whether the estimated parameters differ significantly for selected sub-periods.

Keywords: *financial crisis, GARCH, risk premium, structural stability*

JEL Classification*: C22, G12, G17*

1. Introduction

The risk premium is quite an important measure in economic. Both in theory and practice. Not only can it be estimated on different theoretical basis (i.e., one usually considers term "risk premium" for many slightly different concepts like "required market risk premium", "historical market risk premium", "expected market risk premium", "implied market risk premium", etc.).

For example the expected risk premium is a measure of expectations on the future returns over some small risk investments (usually: treasuries). Required risk premium is connected with portfolio diversification. Finally, the implied risk premium is derived from pricing models under the assumption that the real market can be modeled by a certain description.

Here, the historical risk premium is considered. In particular – the difference between returns from stocks over treasury bonds. Measuring the risk premium is important due to various arguments, indeed. For example, it can be used as some kind of indicator of the risk aversion of investors. Moreover, its estimation is used in estimating the cost of capital and asset valuation (Damodaran, 2011).

In this article the risk premium volatility is studied. In particular, with a help of GARCH model. This model uses two equations: one describing the behavior of the risk premium itself, and the second – describing volatility. In other words, the second equation is responsible for the variation of the error term from the first equation. Choosing such a model is reasonable, because it is expected that the risk premium is characterized by volatility clustering, i.e., there are periods of high volatility, then periods of small volatility, and so on.

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2. Literature Review

Quite comprehensive review of various kinds of risk premium is presented by Fernandez (2004). Estimations of various types of risk premium for many countries are presented by Damodaran (2015). Yet, these estimates are based on quite long time horizon. Yet, taking too long time horizon can make a significant bias, as too long investments seem practically useless. Indeed, various methodologies and restrictions lead to very different outcomes in the estimation of a risk premium.

The discussion from the theoretical point of view is still interesting for economists. Among plenty of literature, for example, works of Asness (2000), Duang and Zhang (2013), Mehra and Prescott (1985) and Sfiridis (2012) can be of a first interest.

Chen et al. (1990) discussed the time-variability of a risk premium. Recently, Heryan (2014) discussed the volatility of a risk premium in context of GARCH models. For the recent empirical estimations of a risk premium in Poland, the Reader should consult, for example, papers of Sekuła (2011) and Waszczuk (2013). For example, Sekuła (2011) estimated the risk premium for Poland in the period of 1995 – 2010 to be between 2.9% and 8.6%.

On the other hand, in 1986 Bollerslev proposed a GARCH model. In particular, the variable x_t is said to follow AR(m)-GARCH(p,q) process, if

$$x_t = a_0 + a_1 \cdot x_{t-1} + \ldots + a_m \cdot x_{t-m} + e_t \,,$$

where $e_t = u_t \sqrt{h_t}$ and $u_t \sim N(0,1)$ and

$$h_t = c_0 + c_1 \cdot (e_{t-1})^2 + \ldots + c_p \cdot (e_{t-p})^2 + d_1 \cdot h_{t-1} + \ldots + d_q \cdot h_{t-q} \,.$$

Actually, the above equations describe a particular kind of GARCH-type model, i.e., AR-GARCH. Yet, this type was found were useful in applications. Especially, in the context of Polish capital market (see, for example: Fiszeder, 2009; Fiszeder and Kwiatkowski, 2005; Małecka, 2011).

More information about GARCH family of models can be found in the book of Xekalaki and Degiannakis (2010) and a chapter by Zivot (2009). Later, in this paper, also the methods described by Alexander (2001) and Andersen et al. (2009) will be used.

Yet, as the mentioned researches for Poland indicate AR-GARCH type model is especially useful. Usually, in practice there is no need to consider GARCH(p,q) with p or q higher than 1 (Hansen et al., 2005; Chou, 1988; Matei, 2009).

3. Methodology

The daily data for WIG (Warsaw Stock Exchange all-stocks index) and the yield of 10-year treasury Polish bonds were obtained from Stooq. If wig_t denotes the level of WIG index in points and ytm_t – a 10-year bond rate in percentages, and t stands for time index, then the daily risk premium, x_t, is computed by the following formula:

$$x_t = [\, (wig_t / wig_{t-1}) - 1 \,] - [\, (1 + ytm_t)^{1/360} - 1 \,] \,.$$

It should be noticed that usually a risk premium is considered for much longer time horizon than one day. However, the aim of this research is to analyze such a specific "high-frequency" estimate. (Yet, notice that this has nothing to do with high-frequency data which term is used to describe sec or min frequencies or market microstructure, etc.). It is just emphasized that more frequent than usual time series is considered.

The computations were done in R programme (R Core Team, 2015) in rugarch package (Ghalanos, 2014).

4. Analysis and Results

The graphical analysis suggests that the obtained time series is stationary and there exists the clustering of variance (see Fig. 1). Therefore, it seem reasonable to use the GARCH methodology further.

Yet, as mentioned, for example, by Heryan (2014), it seems interesting also to analyze the structural stability if some sub-periods are considered. The initial data consist of 2336 observations beginning on 28/11/2005 and ending on 27/03/2015. On 27/02/2007 Freddie Mac announced that they will no longer buy the most risky sub-prime mortgages and mortgage-related securities. On 15/09/2008 Lehman Brothers filed for bankruptcy protection. On 23/04/2010 Greece supplied for an initial loan from EU and IMF to cover its financial needs for the remaining part of the year, S&P rated Greece's sovereign debt as "junk" and Euro currency declined. Theses events divide the whole analyzed period into 4 sub-periods.

However, first some descriptive statistics are presented for the whole sample. The minimum daily risk premium for the considered period is -7.97% and the maximum one is 6.25%. The mean (arithmetic) is 0.015%, which corresponds to 5.46% annual rate. The geometric mean is 0.0059%, which corresponds to 2.15% annual rate.

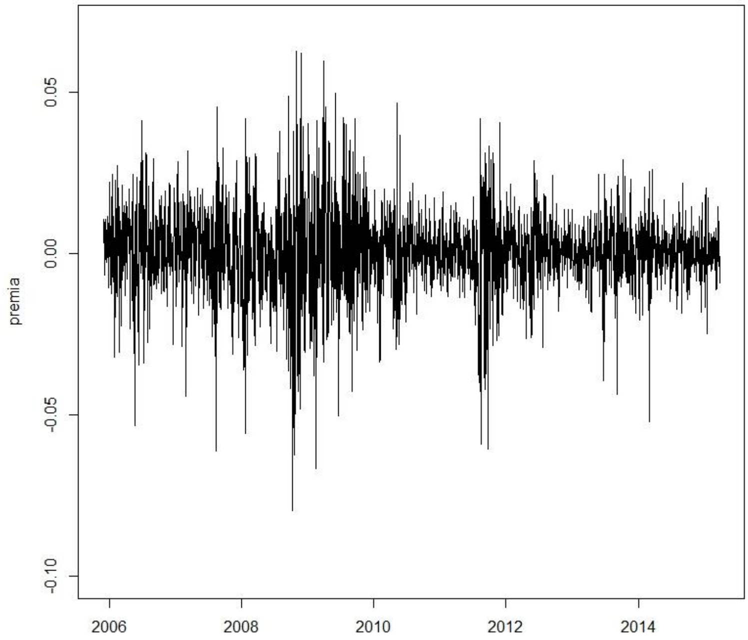

***Figure 1**. Risk premium (x_t)*
Source: Own calculations in R

As stated before, AR(1)-GARCH(1,1) was *a priori* taken as the most suitable type of model for the present research. In particular, it is assumed that

$$x_t = a_0 + a_1 \cdot x_{t-1} + e_t ,$$

where $e_t = u_t \sqrt{h_t}$ and $u_t \sim N(0,1)$ and

$$h_t = c_0 + c_1 \cdot (e_{t-1})^2 + d_1 \cdot h_{t-1} .$$

Table 1. Estimates of AR(1)-GARCH(1,1)

	2005-11-28/ 2015-03-27	**2005-11-28/ 2007-02-27**	**2007-02-27/ 2008-09-15**	**2008-09-15/ 2010-04-23**	**2010-04-23/ 2015-03-27**
Augmented Dickey-Fuller (p-value)	0.01	0.01	0.01	0.01	0.01
ARCH LM (p-value)	0.0000	0.1376	0.0000	0.0000	0.0000
a_0	0.000395 *	0.001668	-0.000723 *	0.000848 *	0.000299 *
a_1	0.067740	0.064227 *	0.038342 *	0.110164	0.058222 *
c_0	0.000001 *	0.000006	0.000015	0.000000 *	0.000002 *
c_1	0.078482	0.051288	0.100333	0.028394	0.078981
d_1	0.914829	0.919600	0.824101	0.966963	0.897321
$c_1 + d_1$	0.993311	0.970888	0.924434	0.995357	0.976302
Ljung-Box (p-value)	0.4689	0.8785	0.8913	0.68690	0.4667
ARCH LM on st. resid. (p-value)	0.6367	0.9175	0.03533	0.3375	0.6125

* not significant at p = 0.05

Source: Own calculations in R

The augmented Dickey-Fuller test allows to assume that all considered time series are stationary (see p-values reported in Tab. 1). If not stated otherwise, the significance level is assumed to be 0.05. For every period, except 28/11/2005 – 27/02/2007, the LM test suggest that there exists the ARCH effect (see p-values Tab. 1). Yet, it is reasonable to perform GARCH models, indeed.

Unfortunately, the parameter a_0 is not stable for all sub-periods. Moreover, it is statistically not significant for all periods, except 28/11/2005 – 27/02/2007. Similarly, the parameter a_1 varies significantly with time periods. Moreover, for there sub-periods it is statistically not significant. It suggests that the AR(1) specification should be somehow modified and is not the best one by itself.

On the other hand, the variance equations present better estimations. Although, the parameter c_0 is not significant for three models, it can be assumed to be equal to 0. The parameter c_1 takes (statistically significant) the smallest value for 15/09/2008 – 23/04/2010 sub-period and the highest for 27/02/2007 – 15/09/2008 sub-period. This can be interpreted as if shocks and innovations would have smaller impact on the present volatility than the past volatility. For the parameter d_1 the conclusions are just opposite. The variance equation seems to be quite stable, except the sub-period 27/02/2007 – 23/04/2010. This suggests that the root period of financial crisis is described by different parameters (see Tab. 1).

Yet, all evaluated models are free of autocorrelation of residuals. This is indicated by high p-values of the Ljung-Box test. Also, the LM test for standardized residuals suggests that after the GARCH type estimation there remained no further ARCH effects (see reported p-values in Tab. 1).

For all sub-periods, except 27/02/2007 – 15/09/2008 and 23/04/2010 – 27/03/2015, sign bias tests (Engle and Ng, 1993) do not indicate any problems (not reported here). In particular, positive and negative innovations affect the future volatility in the same way. The practical aspects of these tests in a more general context and other examples are explained, for example, by Kumar (2014) and Seddighi (2012).

From the news impact curve (see Fig. 2) it can be seen that the impact of shocks on volatility is different in certain periods (Pagan and Schwert, 1990; Jondeau et al., 2007). The highest impact is in the beginning of the financial crisis and the smallest – just afterwards.

Finally, it should be clearly emphasized that even the statistical significance of the AR model does not violate the efficient market hypothesis. This hypothesis requires no arbitrage, but some kind of predictability of returns can remain (Timmermann and Granger, 2004; Timmermann, 1993; Woooldridge, 2013). Moreover, the estimation of the parameters of models is done *ex-post*, i.e., basing on the already known observations. Therefore, it is not known if an information obtained in such a way could have been used in the past. Moreover, no transactional costs were incorporated into the estimated models, etc.

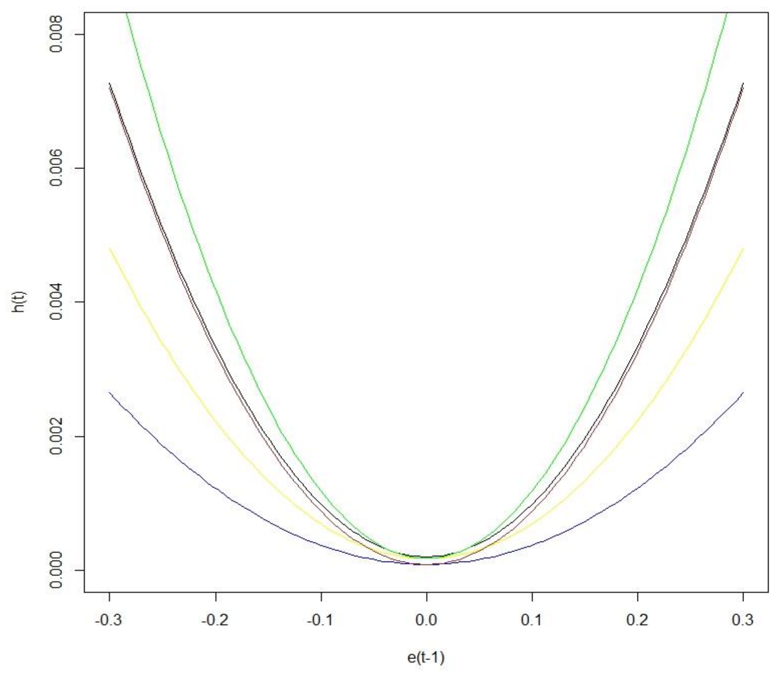

Figure 2. *News impact curves (28/11/2005 - 27/03/2015 black, 28/11/2005 - 27/02/2007 yellow, 27/02/2007 - 15/09/2008 green, 15/09/2008 - 23/04/2010 blue, 23/04/2010 - 27/03/2015 brown)*
Source: Own calculations in R

Of course, also the rolling estimation can be used to determine the discussed structural stability. The first estimation was done after the first 500 observations. Such a number of observations correspond to approximately two calendar years. Then, the re-fitting was done after every 25 new observations, which corresponds to approximately a period a bit longer than a one calendar month. As a result, 74 evaluations of GARCH type models were done. The results are presented on Fig. 3.

It can be observed that in 2009 and 2010 all estimated parameters were very volatile. The parameters a_0 and a_1 are more stable in the period after the occurrence of the recent global financial crisis. However, parameters connected with the variance equation, i.e., c_1 and d_1 are more volatile after the occurrence of the recent global financial crisis. Although, the numerical values seem to follow quite stable paths, the standard deviations of the estimations are very explosive in 2009 and 2010. Also, their confidence intervals significantly widened after the occurrence of the recent global financial crisis (see Fig. 3).

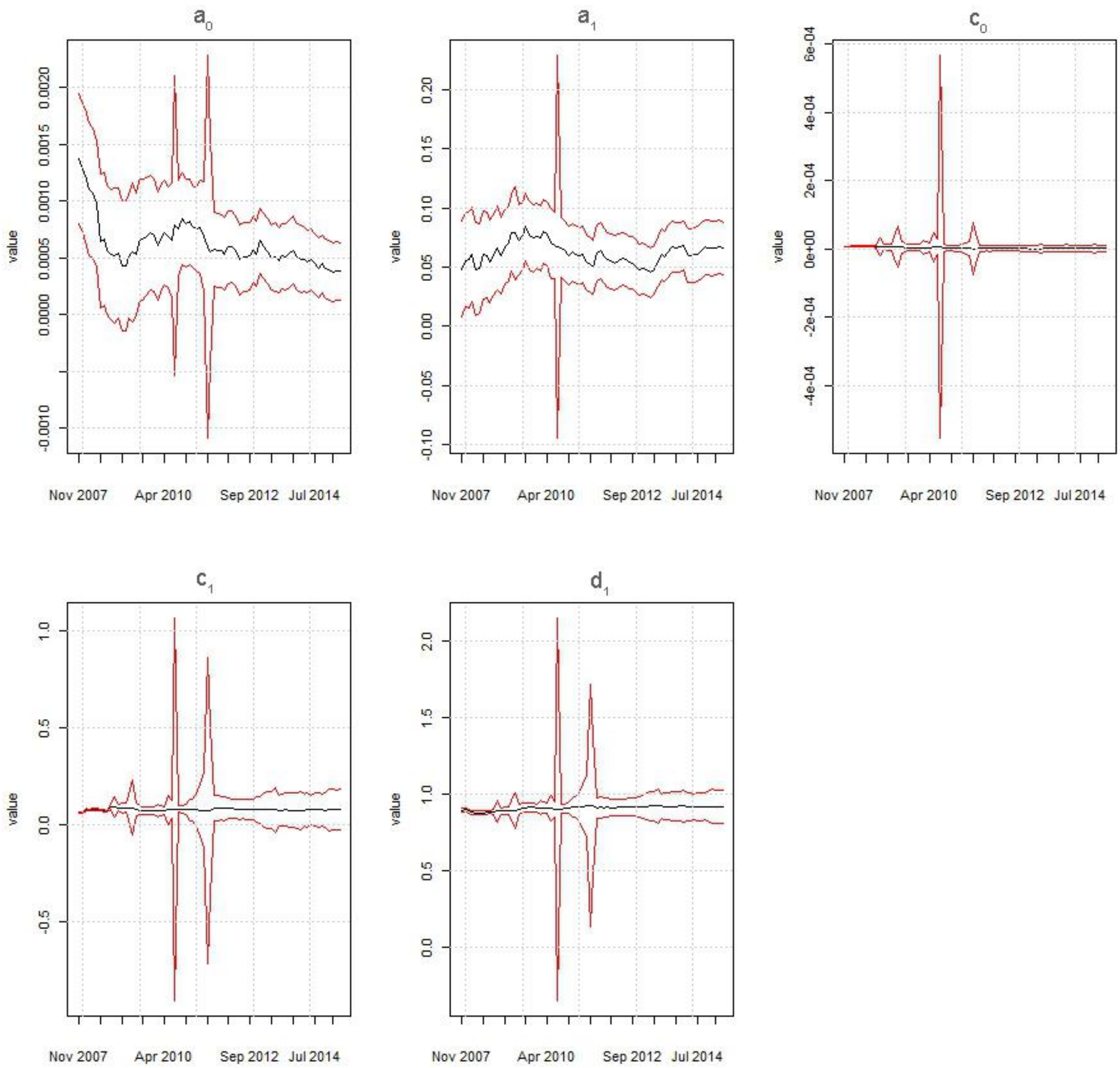

***Figure 3**. Rolling estimations (recursive)*
Source: Own calculations in R

5. Discussion and Conclusion

The daily risk premium was estimated to be between -7.97% and the maximum one is 6.25% in the period of 28/11/2005 – 27/03/2015. The arithmetic mean was estimated to 0.015% and the geometric mean to 0.0059% (daily). It corresponds to values between 2.15% and 5.46% *per annum*. Although, the base period for computing the premium was just one day, the outcomes are quite consistent with some other researches.

The AR(1)-GARCH(1,1) model estimation failed. However, the estimation of the variance equation was quite successful. This seems to be of the interest of some future researches with a help of the GARCH family of models. In case of the structural stability, a significant evidence was found to support the hypothesis that the parameters of the GARCH model vary significantly with time, depending on the sub-period of the recent global financial crisis. This is also with an agreement with some other researches reported in this paper.

In this sense, there is a clear evidence that investors have different attitude towards the risk in different periods of a business cycle. From the news impact curves, it could be observed that the impact of shocks on volatility has different size depending on the time period. On the other hand, the choice of the time horizon for computing the risk premium was quite specific in this paper. Therefore, it seems interesting to lead similar researches, but with different time horizons.

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