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Evolution of the impact of the interest rates changes announced by Narodowy Bank Polski (NBP) on the financial markets in the high, medium and low level of interest rates environments in Poland

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ABSTRACT

The objective of this study is the analysis of the Polish financial market's responses to interest rates changes announced by the Narodowy Bank Polski (NBP) during the period when they evolved from high to low levels. We use GARCH models and we focus comprehensively on four market segments, i.e.: foreign exchange market, stock market, bonds market and derivatives market. The sample period covers over 17 years from August 2000 until December 2017.

Reactions of the financial market in Poland were measured with respect to the nominal changes in interest rates and to their surprise changes (relative to market expectations).

The main conclusion from our study is that in all the investigated market segments the Polish financial market became consistently less responsive to interest rates decisions in the lower interest rates environment.

Furthermore, stronger reactions in foreign exchange market and in stock market were detected in case of interest rates changing upwards rather than downwards, however in bonds market this effect was opposite. When interest rates were announced at different level than expected, the picture is ambiguous. Moreover, the effects in the conditional variance of the GARCH models indicate the existence of stabilizing effects of the NBP communication on the stock market in Poland, but the estimation results for other market segments are mixed.

JEL codes: E5, E4, G1, F3, C2.

1. Introduction

International empirical evidence suggests that the sensitivity of financial markets' reactions to monetary policy announcements changes along with the variations in the interest rates levels (see, for example, Wu (2016) who analyzed the responses of different instruments to the interest rates announcements in the USA and also a related study by Fausch and Sigonius (2018) who examined the impact of surprise changes in the ECB monetary policy on the market in Germany).

In this paper, we investigate if similar effects existed in Poland when interest rates evolved from high to lower levels over time in the period from the year 2000 until the year 2017.

We focus comprehensively on four market segments across the broader financial market, i.e. foreign exchange market, stock market, bonds market as well as derivatives market.

In our analysis, we measure the reactions of the Polish financial market to the Narodowy Bank Polski (NBP) announcements of interest rate changes. Our sample period covers over 17 years, which includes the periods of high levels and low levels of interest rates. It spans from August 2000, when the NBP started to make on regular basis its announcements regarding the monetary policy data, until December 2017.

The reactions of the financial market in Poland are measured relative to the nominal changes in interest rates and to their surprise changes. The surprise component was extracted by comparing the actual NBP announcements regarding the change of the interest rate with market

expectations. We capture market expectations through the consensus forecasts from Reuters surveys of financial market participants in Poland.

Our study contributes to a broader research area concerning the central banks and the impact of their monetary policy decisions, in particular in emerging markets in the Central and Eastern European (CEE) region, such as Poland.

There is relatively little evidence accumulated yet in the existing literature, which indicates whether the communication of central banks in the CEE economies can reduce market uncertainty or whether they may also create wealth effects through the movements in stock prices and foreign exchange rates etc. in response to their announcements. In this paper, we analyze the impact of monetary policy news of the Narodowy Bank Polski, i.e. the NBP decisions about the changes of interest rates, on the Polish financial market. We provide evidence on how investors react to public information released by the NBP in four main segments of the financial sector: foreign exchange market, stock market, bonds market and derivatives market.

Our paper is conceptually similar to the work by Gómez, Melvin and Nardari (2007), who investigated how the decisions of the European Central Bank (ECB) influenced investors reactions and the movements of the euro exchange rate, and also by Bastidon, Huchet and Kocoglu (2016), who evaluated the effect of the ECB's monetary policy announcements on interbank spreads in the period between July and December 2011 during the Eurozone sovereign debt crisis. Bastidon, Huchet and Kocoglu (2016) found that the ECB's announcements did not have consistently an overall calming effect. For example, although the asset buyout announcements decreased market stress, the liquidity provision releases had a stressing effect, while interest rates and liquidity provision announcements did not have any significant effect at all.

The subject of research in this study is Poland, because it is by far the largest financial market and the biggest economy in the CEE region. For

example, according to the Bank for International Settlements (BIS) triennial reports, the BIS snapshot surveys conducted in 2001, 2004, 2007, 2010, 2013 and 2016 show that its foreign exchange market was roughly twice as large in size as the markets in the Czech Republic and in Hungary (see: Triennial Central Bank Survey (2007, 2010, 2013 and 2016)). The Polish stock market is one of the most dynamically growing one among all the European stock trading centers and it is also the biggest in its region. The Warsaw Stock Exchange (WSE) is the largest market of its kind in Central and Eastern Europe and. For example, in terms of the number of the new initial public offerings (IPOs), in the year 2012 the WSE was the most active market not only in the CEE region but also in Europe. The issuers listed on the WSE represented about 51% companies from the region's exchanges and their share in equities trading in Central and Eastern Europe accounted for over 50% in 2012 (see: Fact Book 2013. Warsaw Stock Exchange (2013)). Another reason for choosing Poland as a subject of this research is that after it implemented critical market reforms in the 1990s, and subsequently joined the European Union (EU) in 2004, it also experienced major institutional and macroeconomic changes, which included central bank development. Last but not least, the Polish central bank NBP has been conducting a transparent communication policy with financial markets and since August 2000 it has been publishing a wide range of macroeconomic data regarding its monetary policy variables. The calendar of these announcements is known to the market participants in advance, so they are always aware of it and they have the opportunity to consider the anticipated release of the future new data by the NBP in their investment decisions.

In this research, similarly to the study by Brzeszczyński, Gajdka and Kutan (2017), we are interested in the uncertainty (i.e. risk) effects and also in the wealth (i.e. price return) effects of the NBP communication of the interest rate changes. Our findings may have significant theoretical and policy implications. The results presented in this paper can shed new light on the

issue regarding how monetary transmission mechanism works in emerging economies, which experience significant institutional and macroeconomic reforms. We provide extensive evidence about the reactions of four market segments, i.e. foreign exchange market, stock market, bonds market as well as derivatives market, which is rarely reported scope of results in the existing literature where most studies are focused usually only on one market segment, and we document how the responsiveness of the broader financial market in Poland to the monetary policy announcements of the NBP has changed when interest rates have been evolving from high-level to low-level environment.

In summary, the main purpose of this study is to answer the question whether the financial market responses to interest rates changes in Poland changed over time depending on the level of interest rates (in particular in low-level interest rates environment) and how they differed across the four analyzed market segments. As mentioned earlier, we focus on Poland due to the fact that it is the largest financial market in the CEE region and it was also one of the first countries in the entire CEE region which implemented transparent communication policies on the broadly defined financial markets (which includes not only the communication of the central bank NBP, which is the subject of analysis in this project, but also transparent communication of the public companies on the Polish stock market, which are listed at the Warsaw Stock Exchange).

The remainder of this paper is organized as follows. Section 2 provides a comprehensive literature review about the impact of public announcements on financial markets with a particular focus on Poland and on other emerging markets. Sections 3 and 4 discuss the data and methodology, section 5 reports empirical results, while the last section 6 presents a discussion of the key conclusions and an indication of some policy implications in relation to the main findings from this study.

2. Literature Review

The review of the existing literature shows that the available empirical results evidencing the impact of public announcements on financial markets and asset prices in emerging market countries, in particular in the CEE region, are still relatively scarce.

We discuss below the selected key studies.

Evidence about the impact of the US monetary policy announcement surprises on equity indexes in developed and emerging markets was provided by Wongswan (2009). Large and significant response of Asian, European and Latin American equity indexes to the US monetary policy announcement surprises were detected at short time horizons. However, in the Wongswan (2009) study, there were no CEE countries included in the analysis.

The behavior of volatilities around the scheduled US macroeconomic announcements on stock markets in several world regions, including the Czech Republic, Poland, Hungary, Slovakia and Russia was investigated by Nikkinen, Omran, Sahlström and Äijö (2006). They found that these markets as a group were not affected by the US announcements.

The impact of foreign macroeconomic announcements (from the US and EU) on stock market returns using the intra-day data from the Czech Republic, Hungary and Poland was analyzed by Hanousek, Kočenda and Kutan (2009). All these markets were subject to direct spillovers from neighboring markets or they were also influenced indirectly through the transmission of macroeconomic news.

A question regarding what types of local and neighbouring country news caused stock market movements during the Asian crisis was investigated by

Kaminsky and Schmukler (2002). Their results show that news about agreements with international organizations and credit rating changes turned out to be most important in explaining large movements in stock prices.

The reaction of Argentina's stock market index, Brady bond prices and peso-deposit interest rates to policy announcements and news reports received by markets during the Mexican crisis of 1994–1995 was examined by Ganapolsky and Schmuckler (2001). The announcements that were perceived as increasing the credibility of the currency board had a positive impact on market returns. Furthermore, Robitaille and Roush (2006) provided evidence about the impact of the US macro data and the FOMC announcements on the stock market index in Brazil and on the yield spread on the Brazilian government dollar-denominated bonds market.

Będowska-Sójka (2016) analyzed trading volume, number of transactions, volatility and market depth, as the liquidity measures, around the time of price jumps on the Warsaw Stock Exchange employing intradaily data and found that macroeconomic and firm specific news are not associated with significant jumps in the liquidity variables, suggesting a limited role of public information releases and a larger role of private information.

Tillmann (2016) examined the impact of the quantitative easing program announcements in the US on the changes in the MSCI emerging market equity price index. The reported results show that the quantitative easing had an influence on the MSCI index returns.

Most of the existing studies for emerging markets have been concentrated predominantly on stock markets. Research for other market segments is still more scarce. Poghosyan, Kočenda and Zemčik (2008) analyzed the Armenian central bank's foreign exchange market interventions and found that they affected public expectations about foreign exchange fluctuations. Loiseau–Aslanidi (2011) reported that sterilized foreign exchange interventions by the National Bank of Georgia increased the volatility (i.e.

conditional variance) of the domestic currency exchange rate against the US dollar. Andritzky, Bannister and Tamirisa (2007) presented investigation of the emerging market bonds reaction to macroeconomic announcements and concluded that all analyzed news affected bonds market volatility. Frömmel, Han and Gysegem (2015) examined the link between jumps in the Hungarian forint / euro exchange rate and news releases. They found that scheduled and unscheduled news announcements explain about half of the significant jumps in the foreign exchange market in Hungary. Caporale et al. (2018) investigated the impact of macroeconomic news on daily exchange rates in a group of emerging markets (the Czech Republic, Hungary, Indonesia, Korea, Mexico, Poland, South Africa, Thailand and Turkey. Macroeconomic news coverage included the data on GDP, unemployment, retail sales and durable goods and it was based on story headlines counts from Bloomberg. They found that macroeconomic news are more important in the case of non-managed currencies. Evidence on the short-run reactions of the emerging financial market in Poland to the NBP central bank monetary policy announcements measured by changes in the official interest rate was reported by Serwa (2006), who found that the short-term interest rates responded to the official interest changes but not the long-term interest rates, stock indices and foreign exchange rates. The unexpected monetary policy changes had stronger influence on the money market than the nominal changes in the official interest rate on the days of the monetary policy announcements. The impact of statements of the key policymakers related to future monetary policy decisions (verbal statements reported by major news agencies and official communiqués of the central banks) on the exchange rates in three CEE countries: Czech Republic, Hungary and Poland was investigated by Rozkrut et al. (2007). They found that the verbal comments of policy makers influenced the behavior of currency market, however this effect varied among those three countries. The reaction of the currency market in Poland to the NBP communication of the new monetary policy data was examined also by

Brzeszczyński and Kutan (2015), but the investigated period covered only the years from 2000 to 2003. Evidence presented by Brzeszczyński and Kutan (2015) suggests that the NBP actions stabilized the markets in terms of reduced volatility and that they also increased investors' activity.

The literature covering other studies, which focused on the Polish data, includes Ziarko-Siwek (2004), who investigated the market rates' reaction to the NBP reference rate changes in Poland. Włodarczyk (2008) analyzed the impact of the Monetary Policy Council (MPC) members' comments on the prices of FRA contracts, interest rates SWAPs and on the expectations of market participants in Poland in the period from February 2004 to March 2007 and found that MPC through their members' comments may have had influence on market expectations and prices of some financial assets (e.g. FRA contracts). Janecki (2012) examined the responses of the interbank market and bond market to the decisions regarding the NBP reference rate changes in the period 2001-2011. The unexpected rate changes caused stronger interbank rates reaction and a reference rate increase had also a stronger impact than its decrease on the interbank market. Filipowicz (2013) investigated how stock returns reacted to the changes of the NBP reference rate using the data for selected stocks from the WIG20. The results of this study show that only in some cases the stock prices reacted to the NBP interest rate decisions. Kubacki (2014) analyzed how markets in Poland, the Czech Republic and the UK reacted to the central banks' announcements about the decision to change (or to refrain from the change of) the reference rate. This study focused on the instruments representing short-term section of the yield curve, long-term section of the yield curve and the stock market. Saba and Kudła (2014) examined how the changes of the NBP reference rate affected the prices and the volatility of the WIG20 index, as the index of the largest and the most liquid stocks of the Polish capital market, and they detected the impact of the unexpected interest rate changes but not the expected ones.

Like our study, Akhtar et al. (2017) investigated the impact of interest rate news surprises on the returns and volatility of financial markets using GARCH models. Their focus was on both Islamic and conventional stock and bond indices in three Islamic emerging markets (Indonesia, Malaysia and Turkey) and the advanced non-Islamic countries (US, Germany, Italy, UK, Japan, France, Canada and Australia). Regarding bonds, as the Islamic fixed income securities do not have any explicit interest rate returns, their results indicate that interest rate surprises had a bigger impact on the returns and volatility of conventional rather than Islamic bonds. On the other hand, in case of stock returns the interest rate surprises had about the same or smaller impact on the returns and volatility of conventional stocks in comparison with the Islamic stocks.

Evidence on the forward guidance policy credibility in Poland obtained by investigating changes in the professional forecasters' perceived *ex-ante* monetary policy rule associated with the introduction of the forward guidance policy was reported by Baranowski and Gajewski (2016). They found that the Taylor rule was violated in the forward guidance period, which is interpreted as the evidence in favour of the credibility of the forward guidance approach.

The impact of news on financial markets (interbank deposits, bond, currency and stock markets) in the Czech Republic, Hungary and Poland using GARCH models framework was analyzed by Büttner and Hayo (2012). They found that macroeconomic shocks significantly affected short-term interest rates and, to a lesser extent, other financial variables.

A comprehensive analysis of the monetary policy transmission mechanism in Poland was presented also by Kapuściński, Łyziak, Przystupa, Stanislawska, Sznajderska and Wróbel (2014). They found that it is broadly similar to the mechanisms functioning in the developed markets.

However, the existing empirical evidence indicates that the investors in emerging financial markets, and their reactions to news, may be different than

those in the developed countries. For example, Serwa (2006) argues that emerging markets may react poorly to monetary policy events due to weakness of their monetary authorities, limited confidence of investors and inefficiency of their financial markets. Wongswan (2009) provides results showing that the size of equity markets reactions in response to the US monetary news in the sample of 15 emerging and developed markets varies greatly across those countries and that the cross-country responses variation is linked to the proxies of their level of financial integration with the US as the world's leading market. Hausman and Wongswan (2011) analyzed impact of the US monetary policy surprises on equity indexes, interest rates and foreign exchange rates in 49 countries and also found significant variations across them, which was related to the differences in exchange rate regimes and the proportion of asset holdings owned by the US investors in those markets.

The responses of the emerging and developed markets may, therefore, depend on the level of their development, strength of the monetary policy authorities and integration of their markets with the global financial system.

Given that the available results for the emerging markets, especially those in the new EU countries, are still scarce, our study contributes to the existing literature by providing new empirical evidence from this area.

In terms of the links to the existing studies, our research is directly related to the following earlier papers using the data from international markets: Bernanke and Kuttner (2005), Gómez, Melvin and Nardari (2007), Hanousek, Kočenda and Kutan (2009), Melvin, Saborowski, Sager and Taylor (2010), Conrad and Lamla (2010), Hausman and Wongswan (2011), Hayo and Neuenkirch (2012), Wright (2012), Kiley (2014), Swanson and Williams (2014), Gilchrist, López-Salido and Zakrajšek (2015), von Borstel, Eickmeier and Krippner (2016) and Wu (2016). The papers relevant for our project, which used Polish market data, include: Ziarko-Siwek (2004 and 2013), Serwa (2006), Rozkrut, Rybiński, Sztaba and Szwaja (2007), Włodarczyk (2008), Demchuk,

Łyziak, Przystupa, Sznajderska and Wróbel (2012), Janecki (2012), Kubacki (2014), Kapuściński, Łyziak, Przystupa, Stanisławska, Sznajderska and Wróbel (2014), Brzeszczyński and Kutan (2015), Baranowski and Gajewski (2016) and Brzeszczyński, Gajdka and Kutan (2017).

Our study addresses also some of the gaps identified in the emerging markets literature discussed in the review paper by Brzeszczyński, Gajdka and Kutan (2015).

3. Data

The database used in this research includes daily frequency data from the financial market in Poland from its main four segments, i.e. from:

(1) Foreign exchange market

(2) Stock market

(3) Bonds market

(4) Derivatives market.

Our sample covers the period from 1 August 2000 to 31 December 2017.

August 2000 was chosen as the beginning of the entire sample because it is the first month which marks the start of regular announcements of the key monetary policy data made by the Polish central bank NBP.

Total number of the daily frequency observations in the selected sample used in this study is 4544.

In our project we design and estimate the following specific groups of models for the above market segments.

We construct models for the returns of the foreign exchange rates of the PLN exchange rate against major international currencies: PLN/USD, PLN/EUR, PLN/GBP, PLN/CHF and PLN/JPY. This choice of currency pairs is related to their size and market share.

In case of the stock market, we build models for the returns of major stock market indices listed at the Warsaw Stock Exchange (WSE): WIG, WIG20 and sWIG80. This choice of indices is driven by the need to cover different index types, i.e.: broad market index (WIG) as well as the index of the large ‘blue chip’ stocks (WIG20) and the index of the small stocks (sWIG80) for comparison purposes.

For the bonds market, we construct models for the yields of the bonds listed on the Polish market: 1-year bond, 2-years bond and 5-years bond. This choice covers a range of different maturities for the available bonds (however, it needs to be mentioned that we had to omit 10-years bond in our analysis due to the lack of available data for the whole period which we investigated starting from August 2000).

In case of the derivatives market, we build models for the returns of the futures contracts on the WIG20 index.

Table 1 presents the summary of the numbers of individual announcements of the interest rate changes released by the Narodowy Bank Polski in the entire analyzed period from 1 August 2000 to 31 December 2017.

Figure 1 further illustrates the distribution of the NBP announcements of interest rates changes in the whole sample.

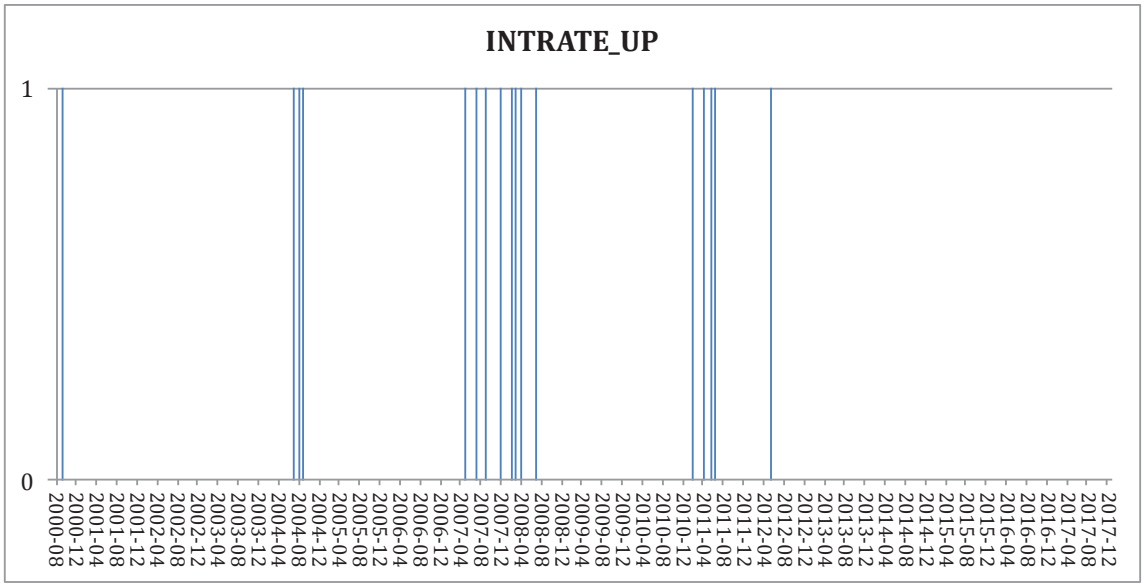
As Table 1 indicates, in the full sample period, which we examined in this study, there were 60 changes of interest rate announced by the NBP, out of which 17 movements were upwards and 43 movements were downwards. The interest rate change was the same as expected by the market in 37 cases, while it was higher than expected by the market (‘positive surprise’) in 7 cases and lower than expected by the market (‘negative surprise’) in the remaining 16 cases.

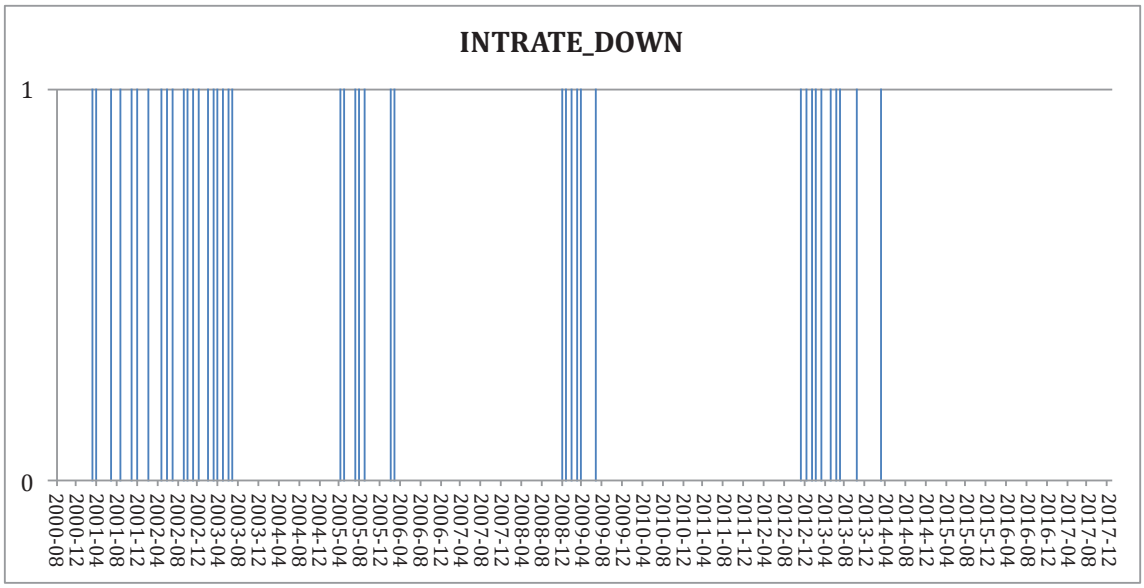
The surprise component in the measurement of the negative surprise and positive surprise changes was extracted by comparing the actual NBP announcements regarding the change of the interest rate with market expectations. The market expectations were captured based on the analysis of the data about the consensus forecasts from Reuters surveys of financial market participants in Poland.

Table 1. Narodowy Bank Polski (NBP) interest rate announcements relative to market expectations in the period: 1 August 2000 - 31 December 2017.

Event:	Number of announcements:
Interest rate change	60
Interest rate change upwards: + 150 bps + 50 bps + 25 bps	17 1 2 14
Interest rate change downwards: - 25 bps - 50 bps - 75 bps - 100 bps - 150 bps	43 22 12 2 3 4
Interest rate change the same as expected by the market	37
Interest rate change higher than expected by the market ('positive surprise')	7
Interest rate change lower than expected by the market ('negative surprise')	16

Figure 1. Distribution of the NBP announcements of the interest rates changes in the period: 1 August 2000 - 31 December 2017.





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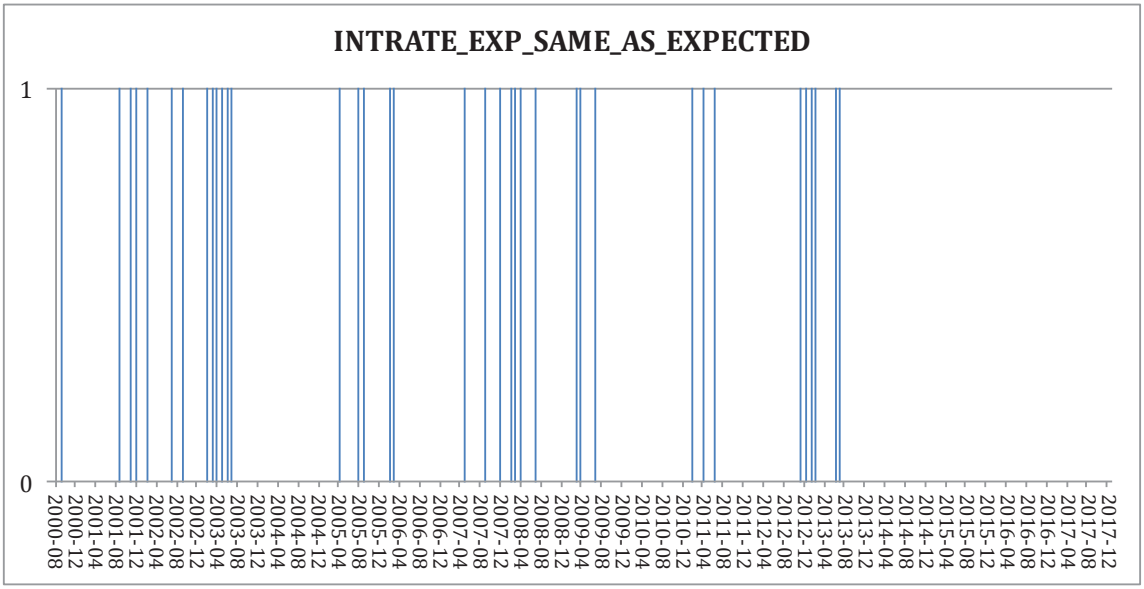


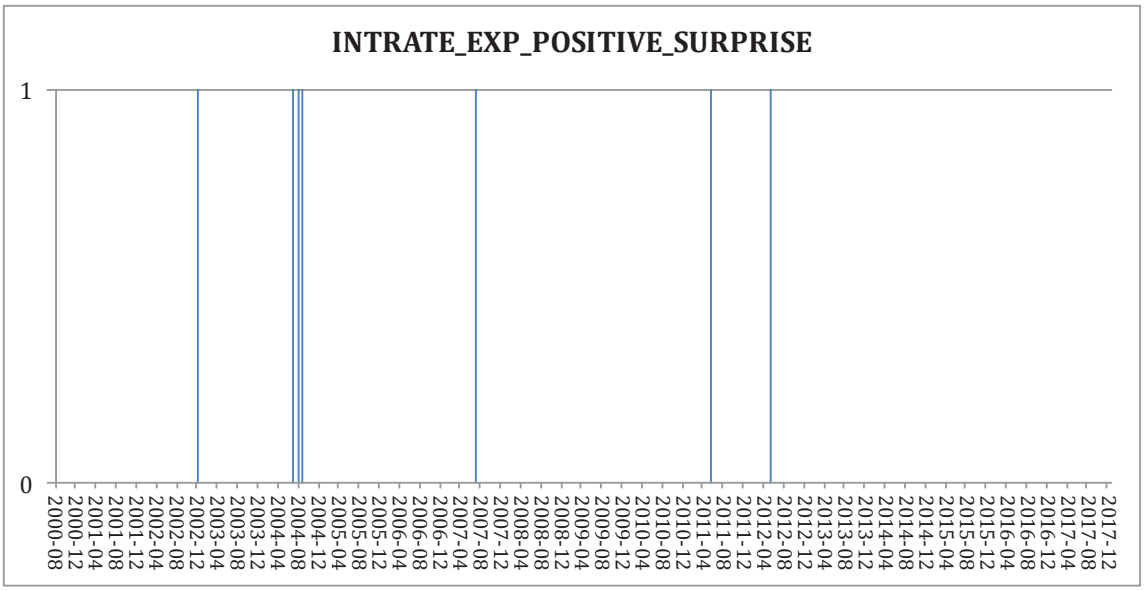
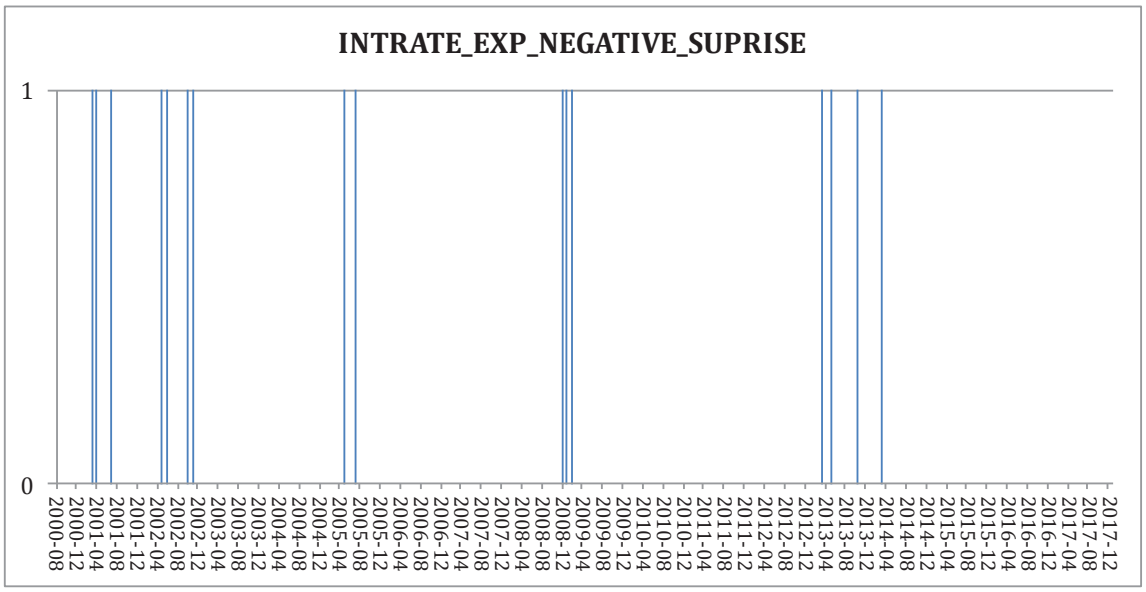


Figure 1. (continued)

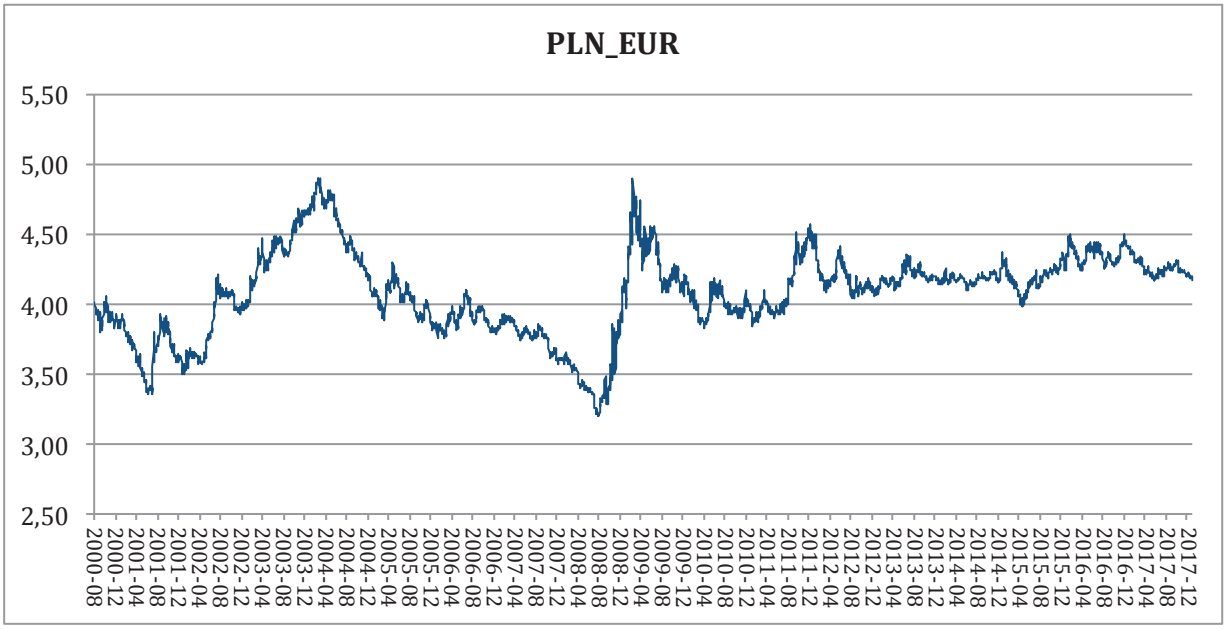


Additionally, we compared and confirmed this survey data with consensus views found in historical articles from the news agencies, which were published before the announcements of the Monetary Policy Council decisions.

Figures 2–13 present the data for all the remaining variables (for levels and returns / percentage changes), which we used in our models as the dependent variables.

Sources of data in our database include: Narodowy Bank Polski (the data for announcements dates and interest rates data), ThomsonReuters (expectations from Reuters surveys), Datastream and Bloomberg (financial markets data from all the analyzed segments).

Figure 2. PLN/EUR exchange rate and returns.



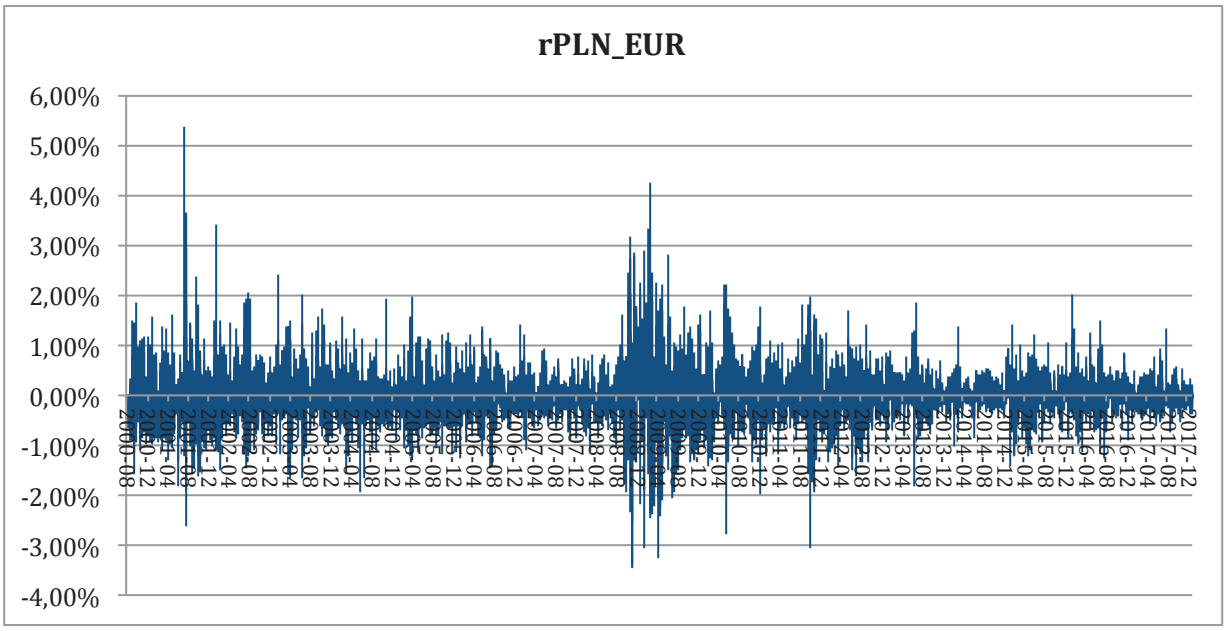
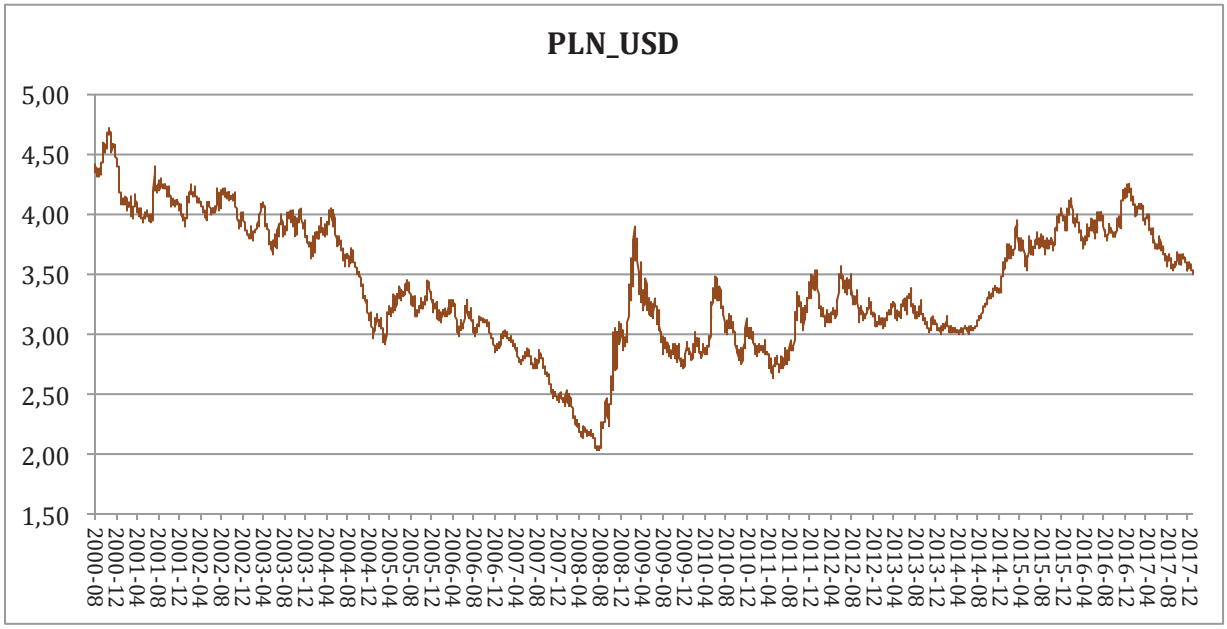


Figure 3. PLN/USD exchange rate and returns.



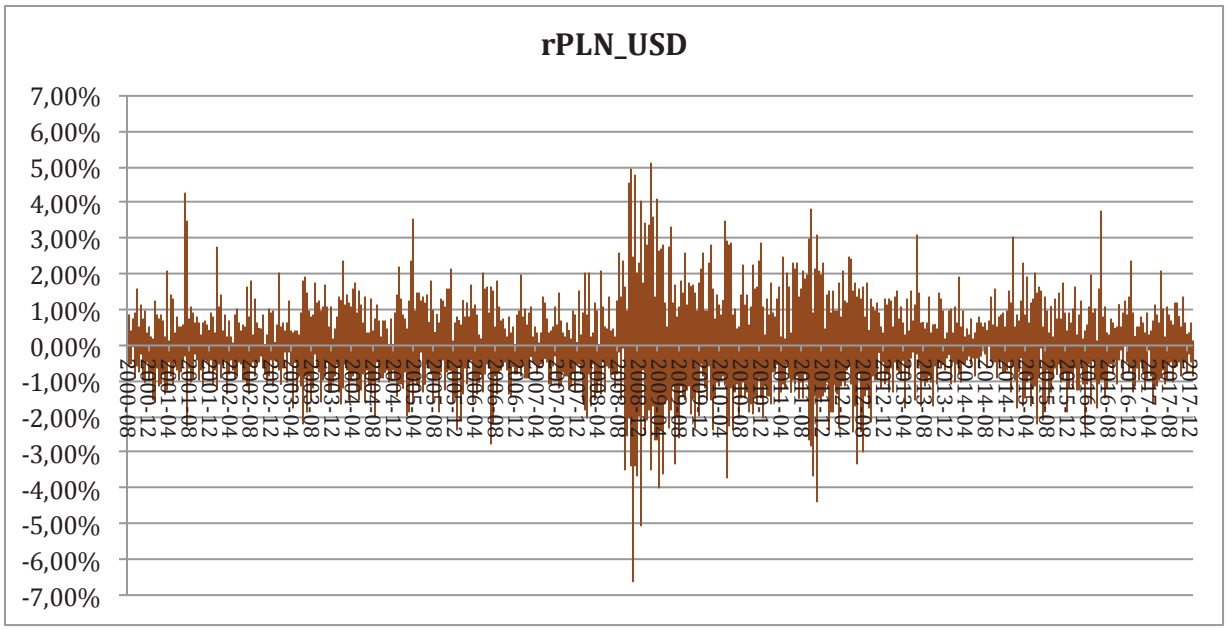
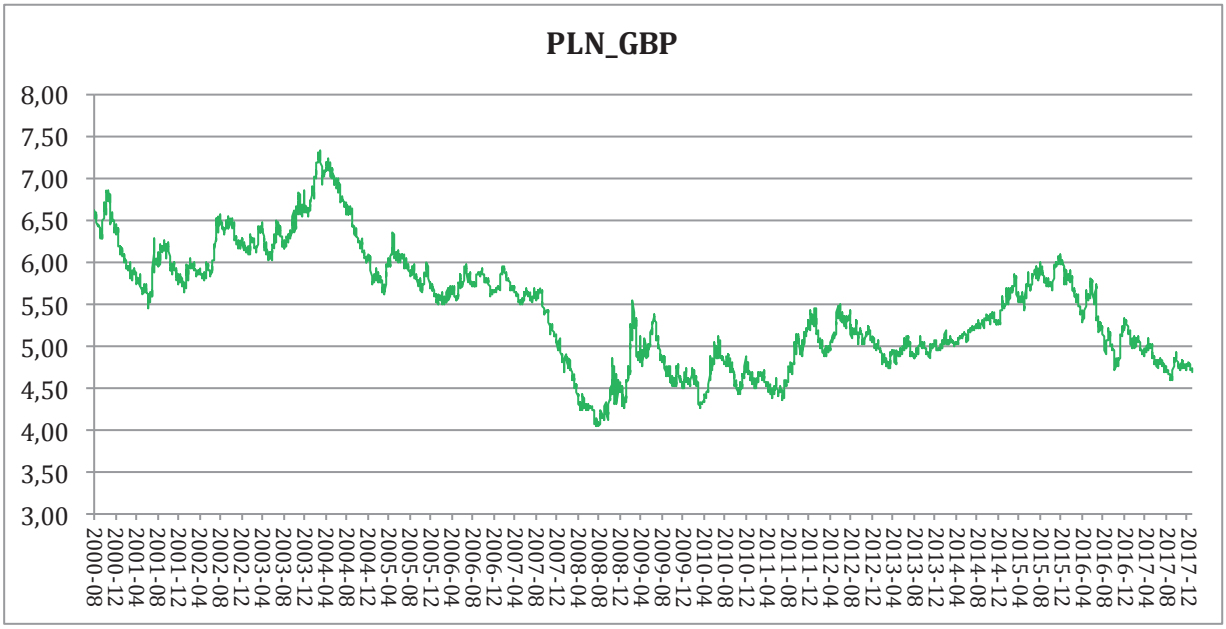


Figure 4. PLN/GBP exchange rate and returns.



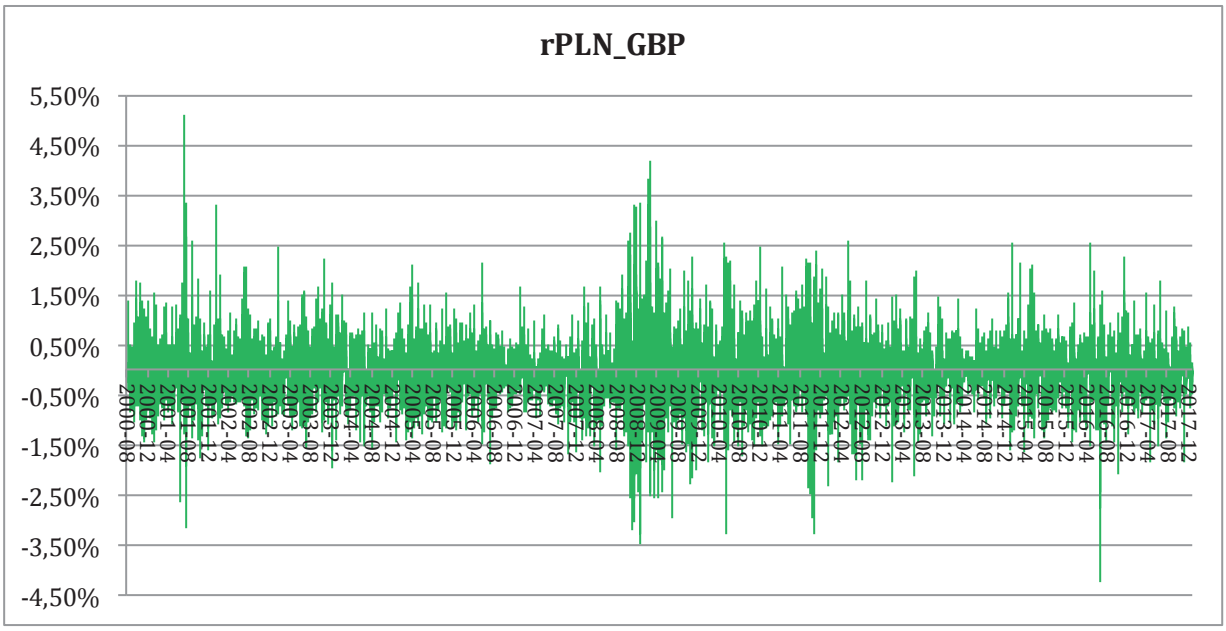
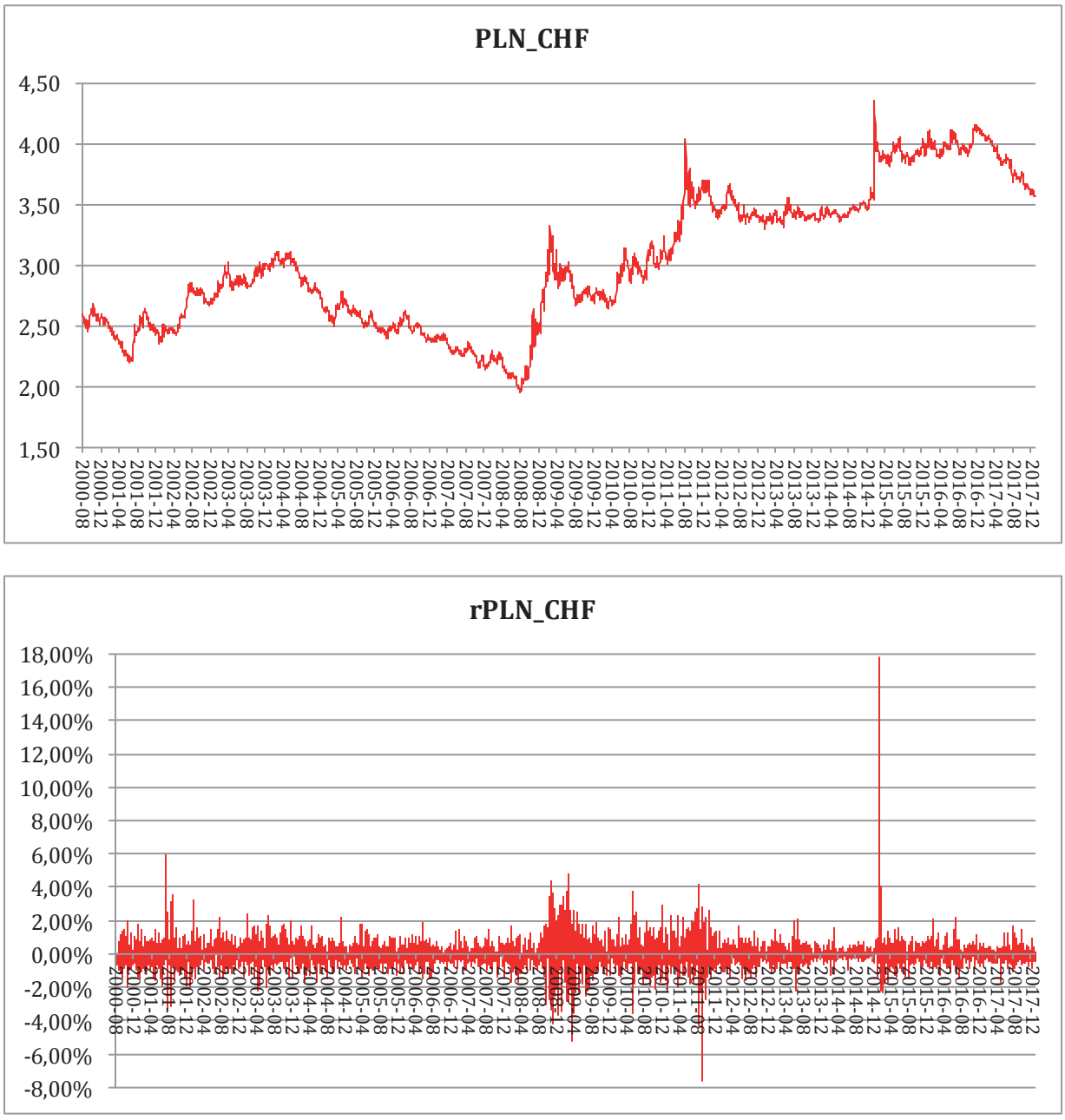
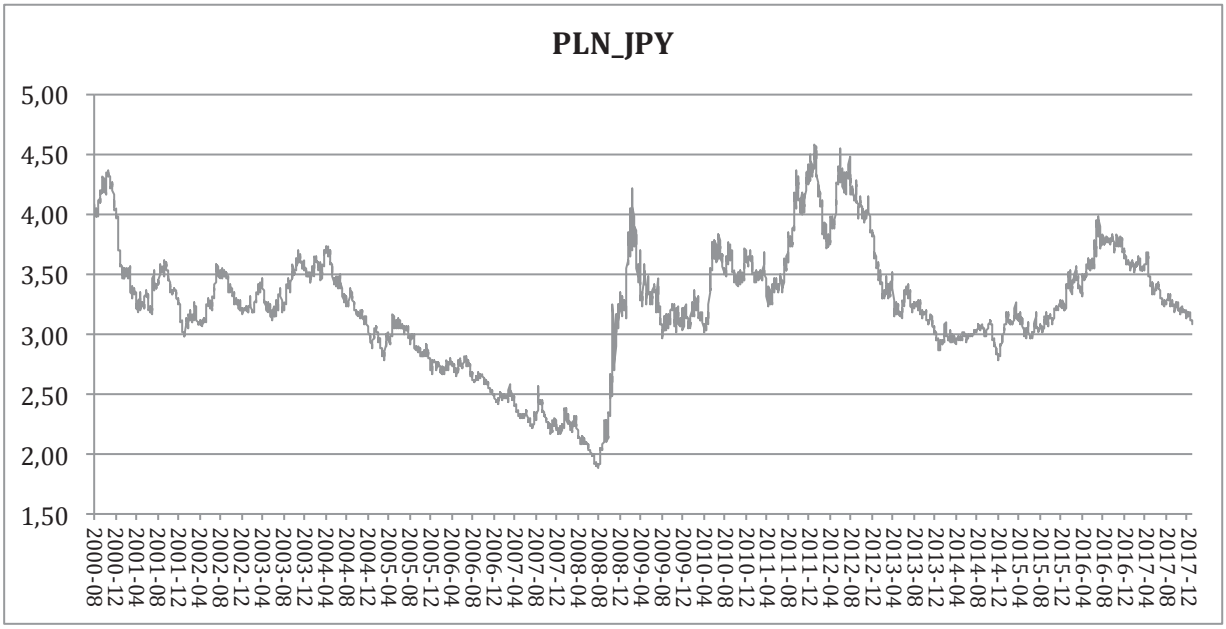


Figure 5. PLN/CHF exchange rate and returns.



Note: The spike in the PLN/CHF exchange rate on 15 January 2015 is associated with the, so called, "Black Thursday", when the Swiss National Bank abandoned the ceiling policy which in the past aimed to defend the value of the Swiss franc. This decision triggered substantial movements of the Swiss franc exchange rate against all other international currencies on 15 January 2015.

Figure 6. PLN/JPY exchange rate and returns.



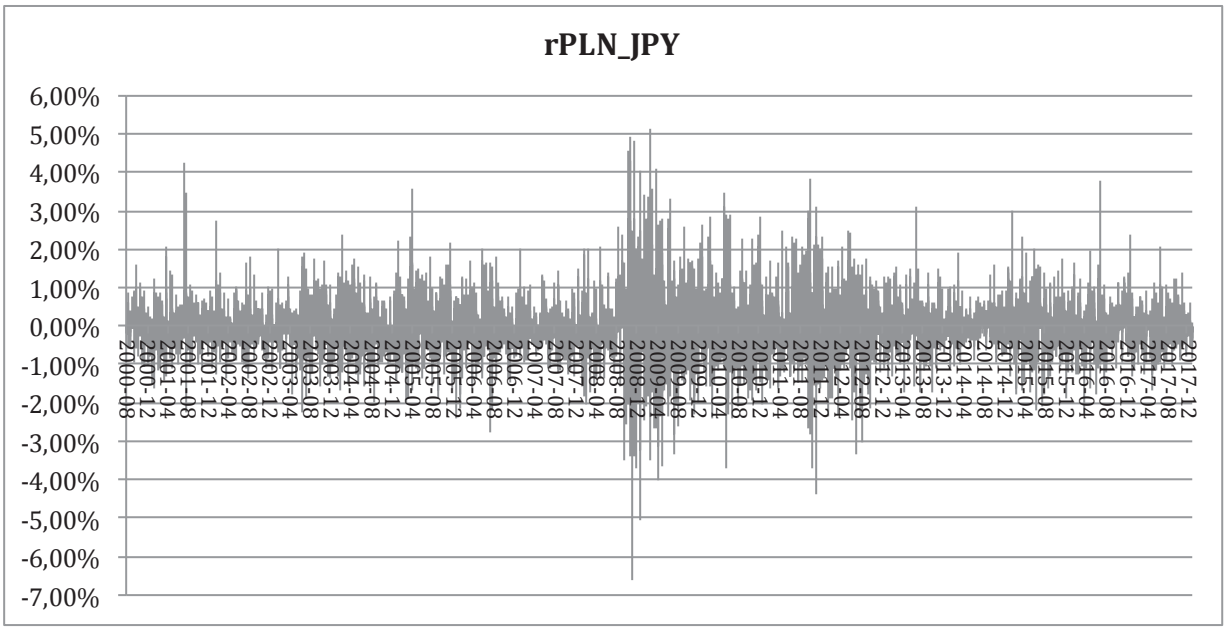


Figure 7. WIG index value and returns.

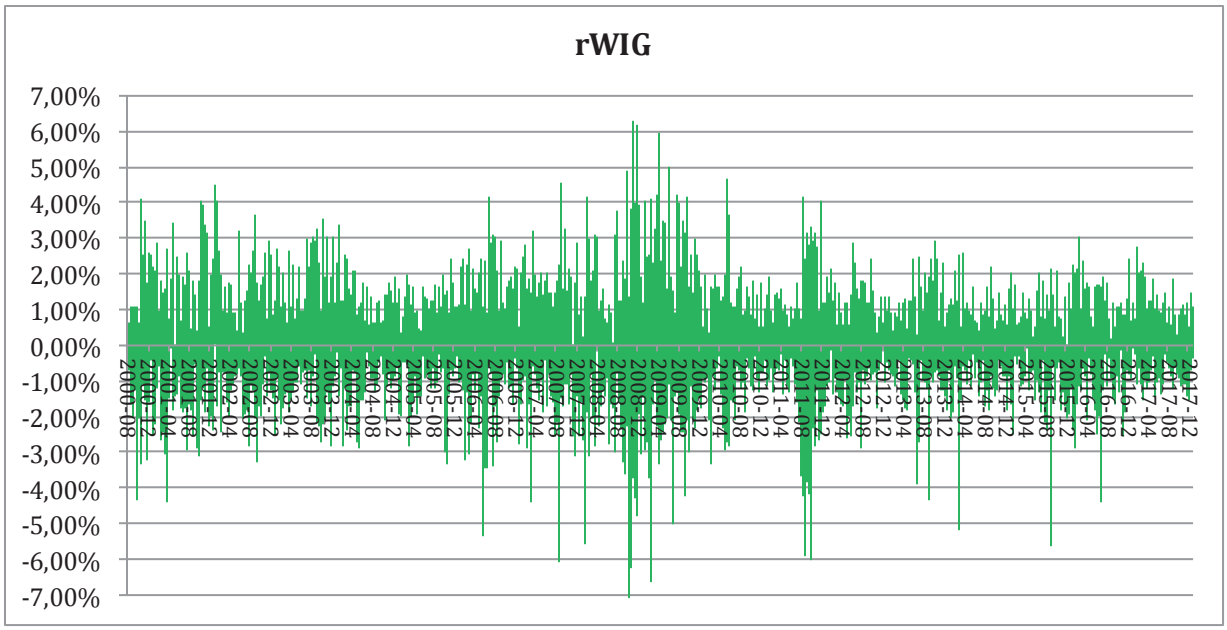
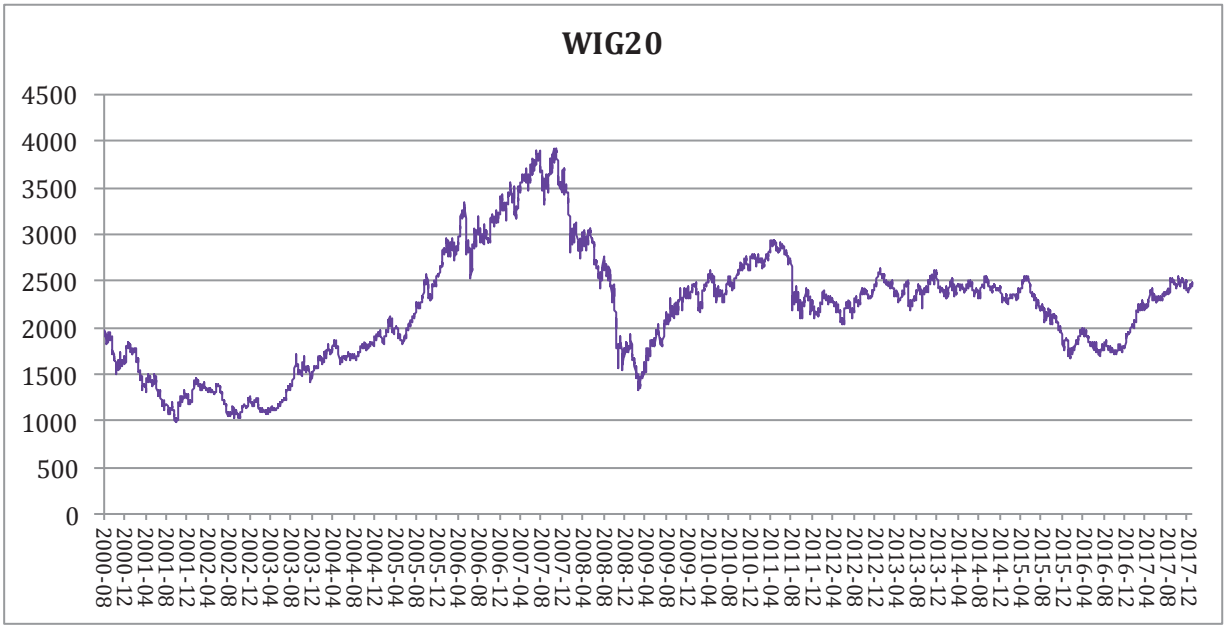


Figure 8. WIG20 index value and returns.



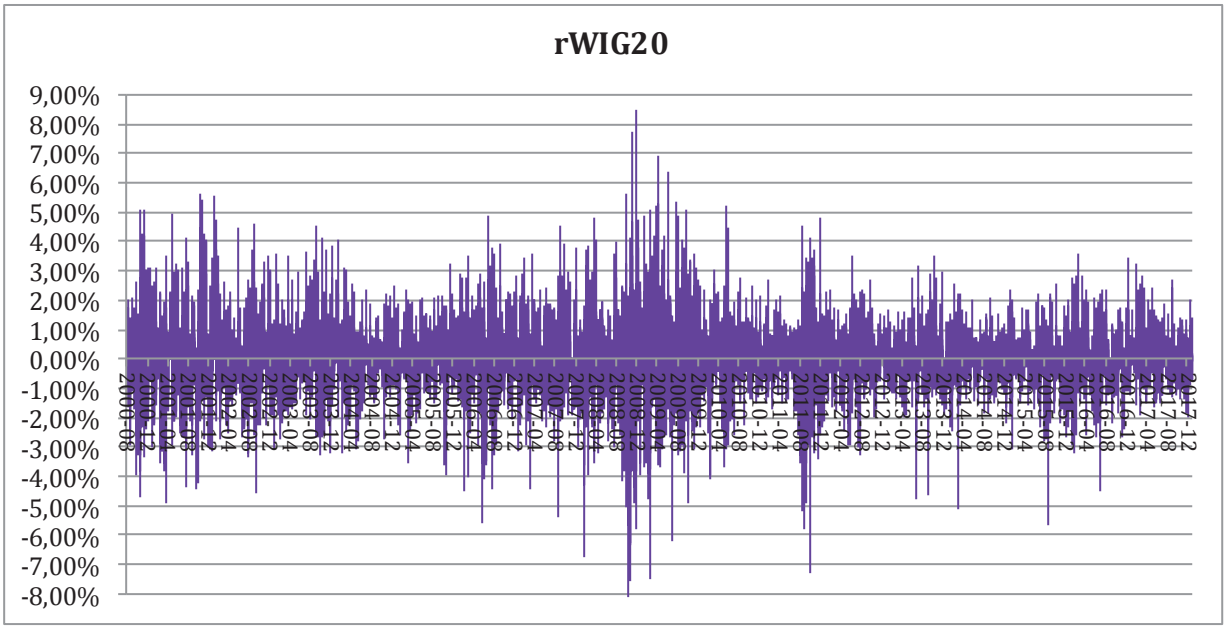
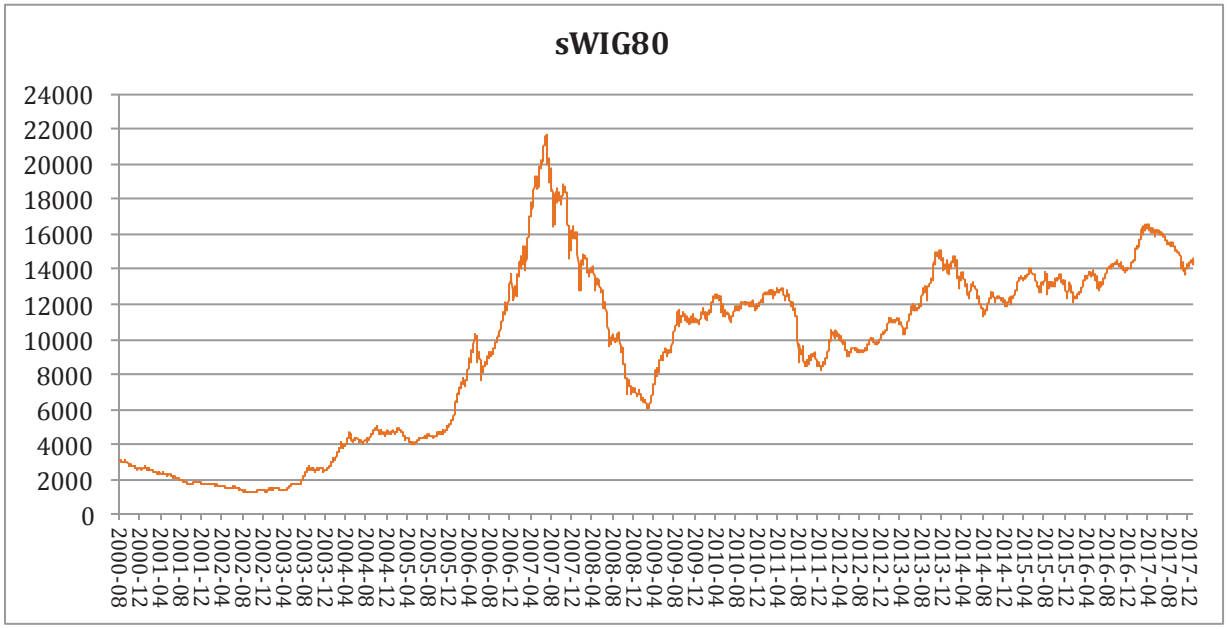


Figure 9. sWIG80 index value and returns.



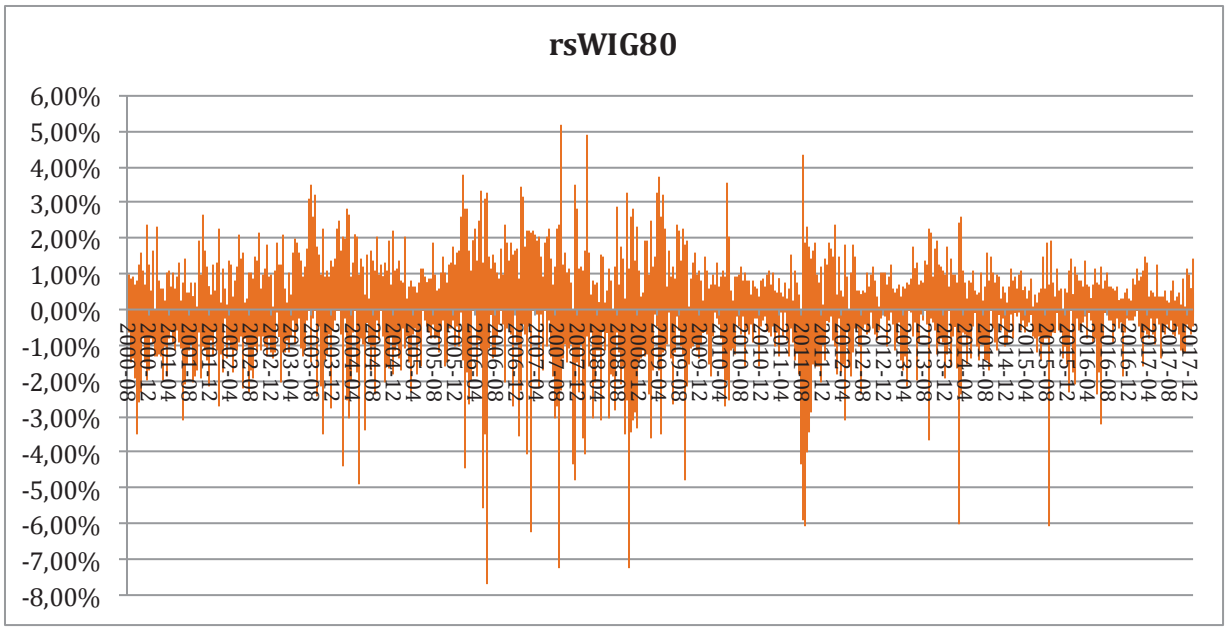
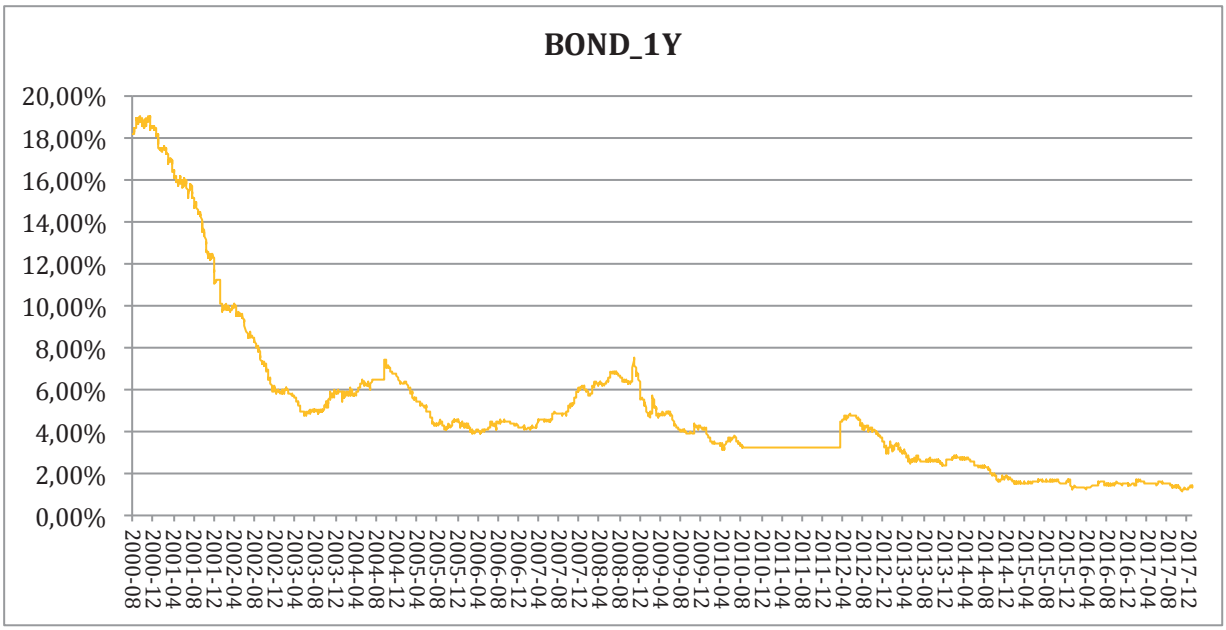


Figure 10. 1-year bond's yield and percentage changes.



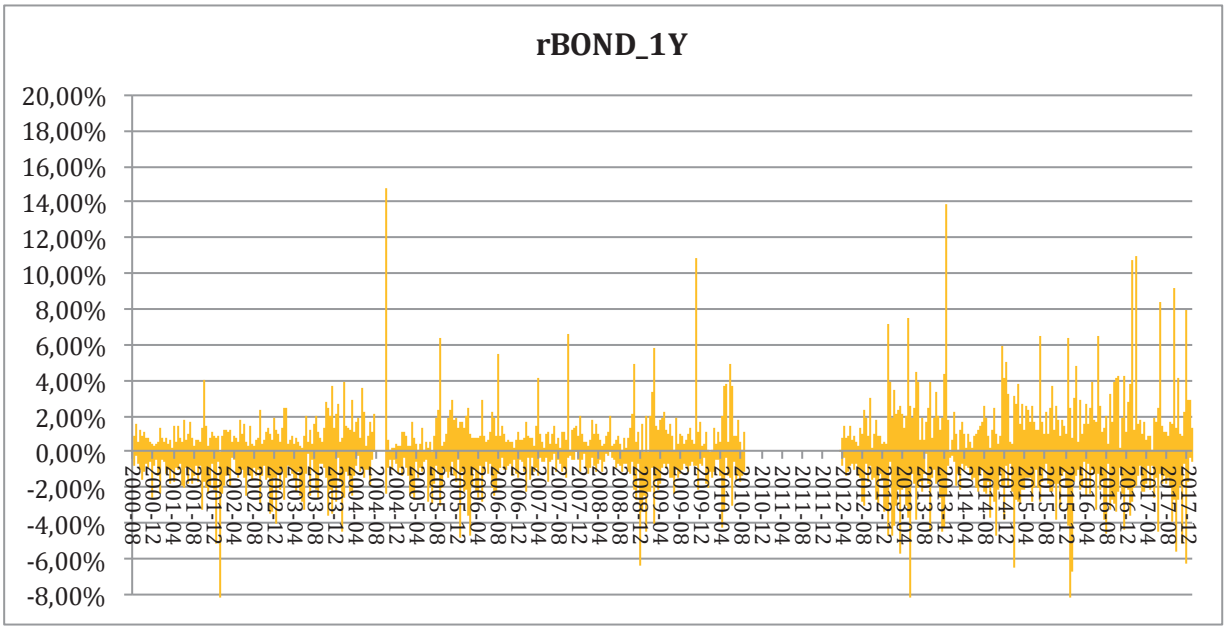
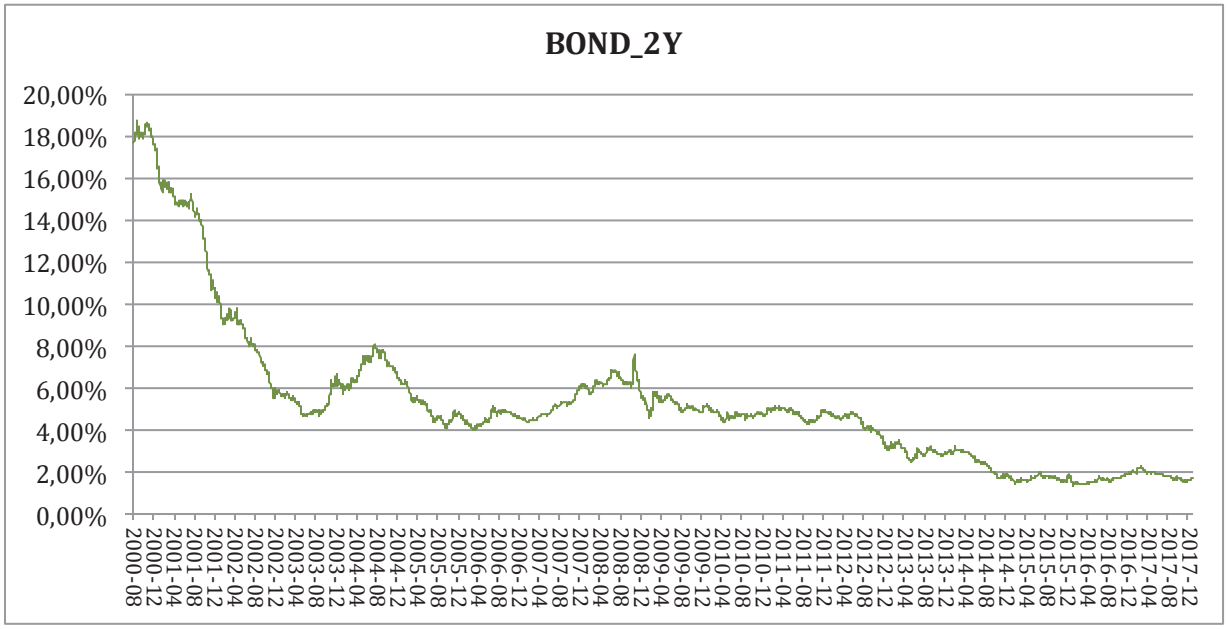


Figure 11. 2-year bond's yield and percentage changes.



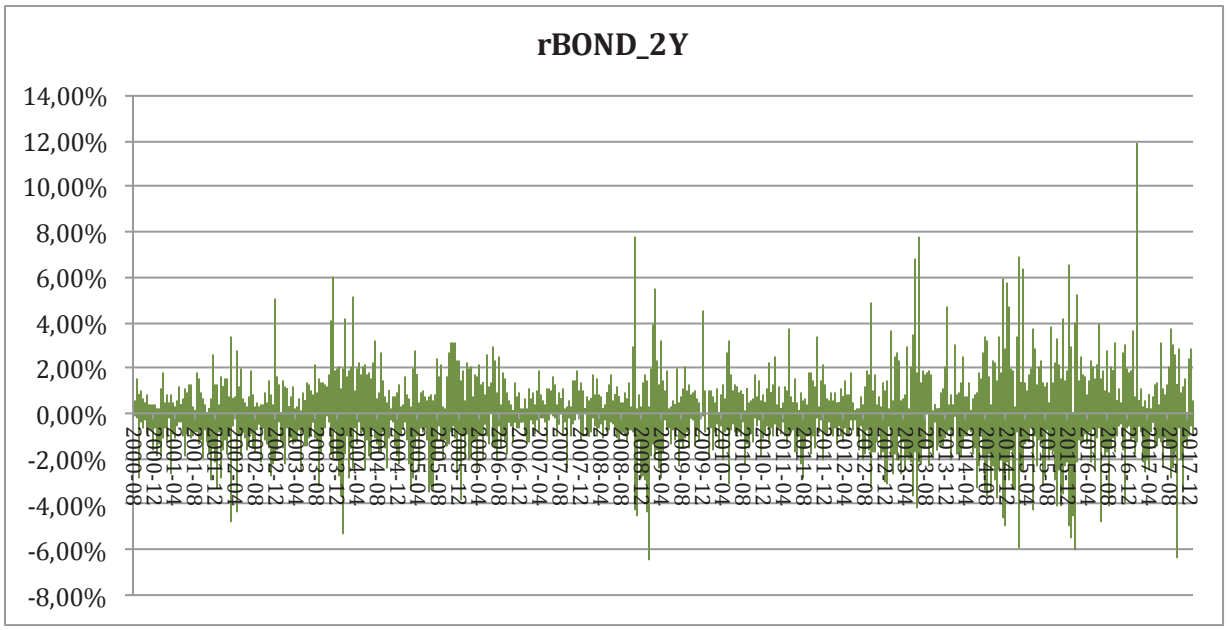
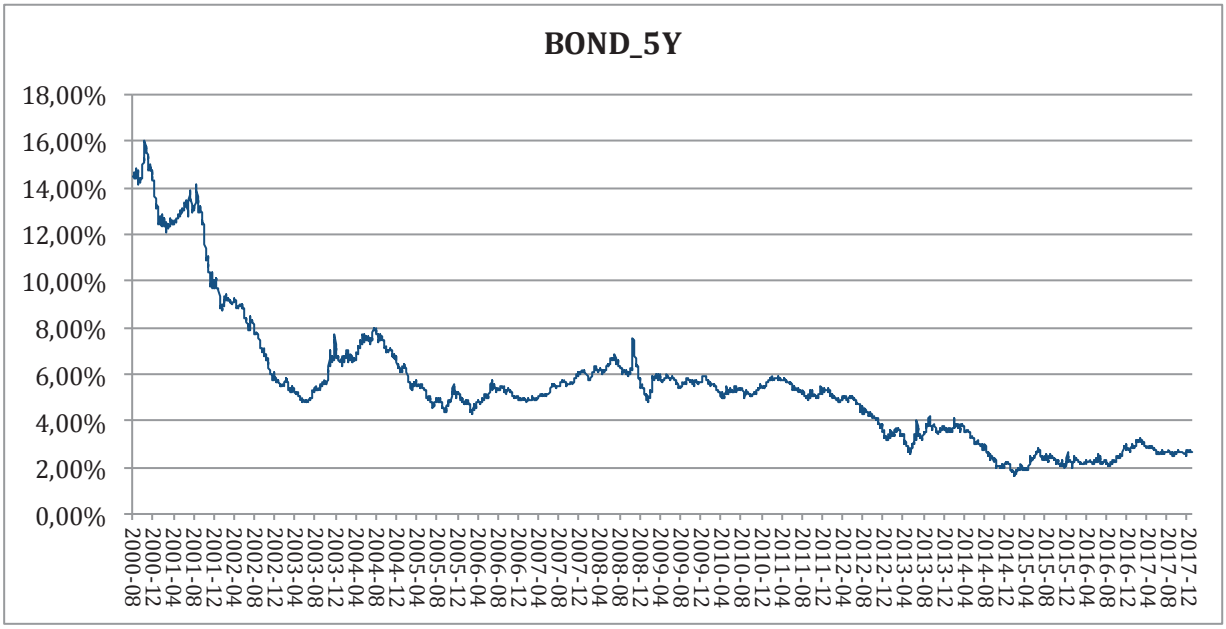


Figure 12. 5-year bond's yield and percentage changes.



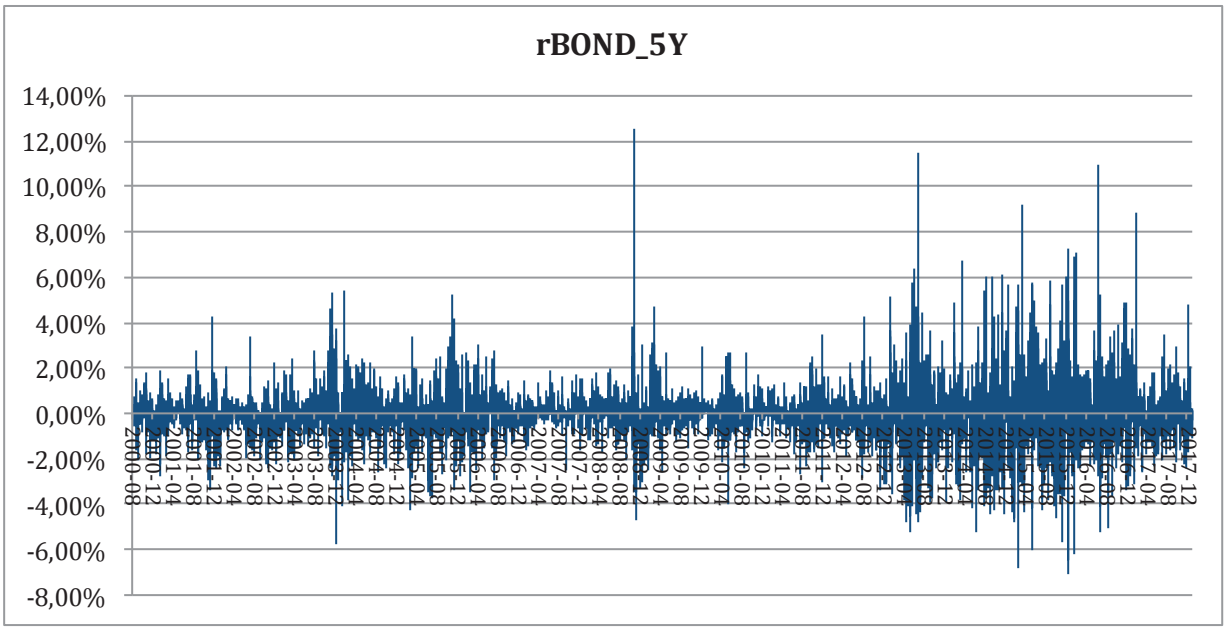
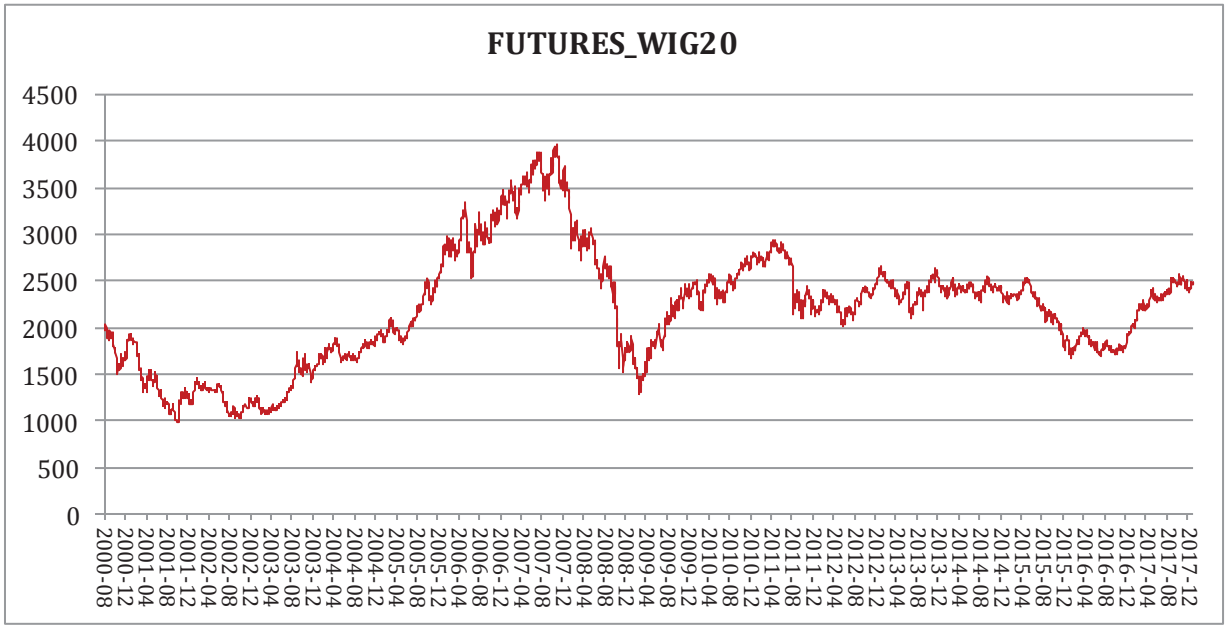
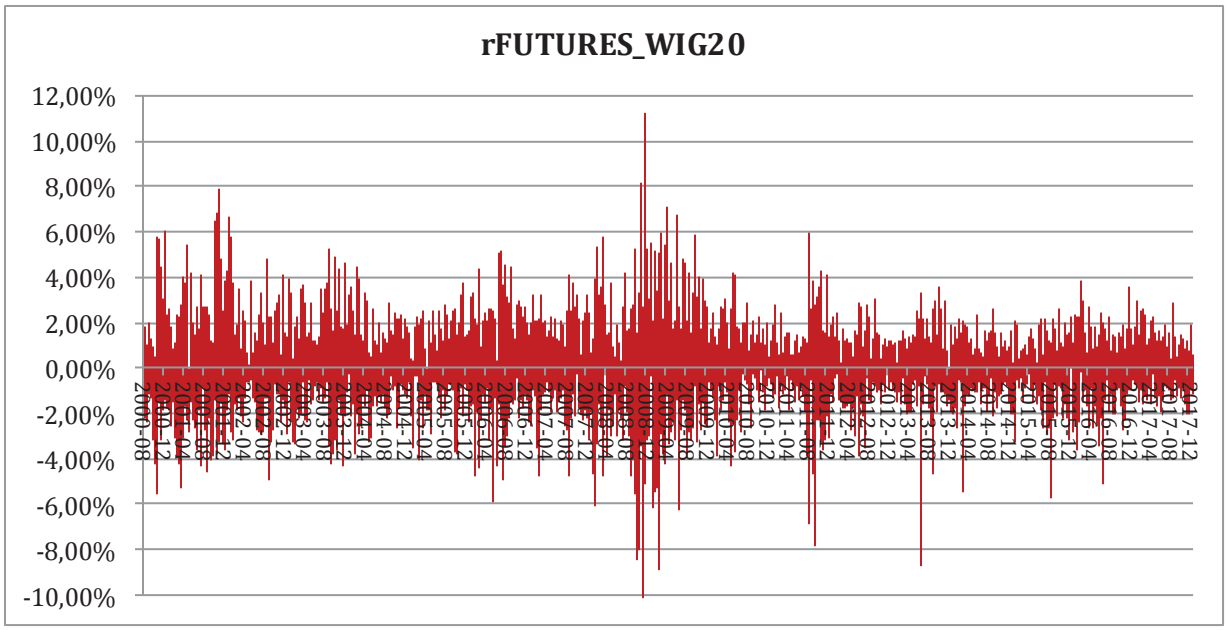


Figure 13. Futures on WIG20 index value and returns.





4. Methodology

We model the reactions of the financial market in Poland in its four different segments and we use dummy variables to capture the NBP announcements effects.

Due to the fact that strong ARCH effects were detected in all models, we adopt GARCH methodology of Engle (1982) and Bollerslev (1986) as our modeling approach. GARCH models are a natural and very convenient methodological framework to investigate the effects of announcements in both the mean equation and the conditional variance equation. Therefore, we introduce the dummy variables in both the mean equation and the conditional variance equation in all models.

The impact of the NBP communication with financial markets is captured by constructing dummy variables for interest rate change announcements for the announcement day (i.e. day t). We investigate models with simple dummy variables for the announcements days when:

(i) interest rates went up or down

and

(ii) announcements of interest rates changes were the same or different from market expectations.

As mentioned earlier, for the construction of the surprise interest rate changes dummies we used the consensus forecasts from Reuters surveys of financial market participants in Poland.

We estimated the following GARCH(1,1) models with the NBP interest rate announcement dummies introduced in the mean equation and in the conditional variance equation:

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \xi_t \quad (1)$$

$$h_t^i = \beta_0 + \beta_1 \cdot \xi_{t-1}^2 + \beta_2 \cdot \sigma_{t-1}^2 + \beta_3 \cdot DUM_t \quad (2)$$

for instrument i where:

r_t^i – is the daily return of the relevant instrument i

and

DUM_t – is the dummy variable capturing the relevant interest rate changes.

We designed such structure of our models following the findings from Cheung and Ng (1996), who argued that the failure to include the dummy variables, which are significant in the variance equation of an ARCH class model, in the mean equation may affect the estimation results. Hence, we adopted this approach and in all models the parameters for the dummy variables are estimated jointly (i.e. in one estimation for the mean equation and for the conditional variance equation).

In all models we also tested for autocorrelation and heteroscedasticity.

If autocorrelation was detected, we removed it by imposing an appropriate structure of AR and / or MA terms.

In cases when heteroscedasticity was persistent, we estimated higher order of GARCH models or other functional forms (e.g. EGARCH etc.), which was necessary to remove any remaining heteroscedasticity effects.

5. Empirical Results and Discussion

In order to capture the reactions of the financial market in Poland in its four segments in the high-level and low-level interest rates environments, we divided the entire sample (covering observations: 1 – 4544) into two equal sub-samples:

- High interest rates period (sub-sample: 1 – 2272)
- Low interest rates period (sub-sample: 2273 – 4544).

We also performed a number of robustness checks by dividing the whole sample period into the following other sub-periods:

- Alternative sub-periods with different division dates
- Different other numbers of sub-periods.

Below we discuss all results in the individual sub-sections distinguishing between the effects in the mean equation and the effects in the conditional variance equation across all four market segments.

5.1. Effects in the Mean Equation

In the first step, we focus on the analysis of the interest rates announcements effects in the mean equations.

5.1.1. Foreign Exchange Market Models

Table 2 presents the estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1) from the GARCH model (1) - (2) of the PLN/EUR foreign

exchange rate returns.[1] It evidences statistically significant reaction of the PLN/EUR foreign exchange rate returns only to the interest rate change upwards in the entire sample period and in the first sub-sample.

Both estimates are negative and significant at the level 5% and 1%, respectively. However, in the second sub-sample, the reactions to this particular announcement and to other announcements are not statistically significant.

Tables 3-6 illustrate similar effects for other foreign exchange rates against the Polish zloty. In case of the PLN/USD and PLN/CHF there is a dominance of statistically significant results in the first sub-period. However, in the PLN/GBP and PLN/JPY models no dummy variable appears significant in any period.

Overall, the results from Tables 2-6 indicate the existence of the weakening effect of the Polish foreign exchange market reactions to the NBP interest announcements over time as the interest rates have been moving to low-level environment.

[1] We adopt the notation for the foreign exchange rates consistently throughout this entire report, within which the exchange rate defined as A/B means the number of units of currency A against one unit of currency B. For example, the rate: PLN/EUR = 4.35 means 4.35 units of PLN which are exchangeable for 1 EUR.

Table 2. Estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1):

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \xi_t$$

from the GARCH model (1) - (2) of the PLN/EUR foreign exchange rate returns.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards	Interest Rate Change the same as Expected	Interest Rate Change Higher than Expected (i.e. 'Positive Surprise')	Interest Rate Change Lower than Expected (i.e. 'Negative Surprise')
	PLN/EUR foreign exchange rate: Full sample					
(1)	Full sample: 1 - 4544	-0.002501 ** (0.001072)	0.000100 (0.000902)	-0.000914 (0.000783)	-0.002256 (0.001769)	-0.000255 (0.001963)
	PLN/EUR foreign exchange rate: 1st sub-sample					
(1)	1st sub-sample: 1 - 2272	-0.003309 *** (0.000623)	-0.000299 (0.001326)	-0.001219 (0.001085)	-0.002780 (0.005105)	-0.000587 (0.004157)
	PLN/EUR foreign exchange rate: 2nd sub-sample					
(1)	2nd sub-sample: 2273 - 4544	-0.001490 (0.001686)	-0.000410 (0.001018)	-0.000643 (0.001262)	-0.001491 (0.002793)	-0.000261 (0.001470)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the mean equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

Table 3. Estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1):

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \xi_t$$

from the GARCH model (1) - (2) of the PLN/USD foreign exchange rate returns.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards	Interest Rate Change the same as Expected	Interest Rate Change Higher than Expected (i.e. 'Positive Surprise')	Interest Rate Change Lower than Expected (i.e. 'Negative Surprise')
	PLN/USD foreign exchange rate: Full sample					
(1)	Full sample: 1 - 4544	-0.003316 * (0.001998)	-0.001306 (0.001277)	-0.002317 ** (0.001173)	-0.000381 (0.003031)	-0.001585 (0.003204)
	PLN/USD foreign exchange rate: 1st sub-sample					
(1)	1st sub-sample: 1 - 2272	-0.003911 ** (0.001888)	-0.001488 (0.001542)	-0.002837 ** (0.001209)	-0.001707 (0.004459)	-0.000805 (0.005070)
	PLN/USD foreign exchange rate: 2nd sub-sample					
(1)	2nd sub-sample: 2273 - 4544	0.000328 (0.005098)	-0.000352 (0.001939)	0.000307 (0.002673)	0.007988 (0.018365)	-0.002960 (0.002645)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the mean equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

Table 4. Estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1):

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \xi_t$$

from the GARCH model (1) - (2) of the PLN/GBP foreign exchange rate returns.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards	Interest Rate Change the same as Expected	Interest Rate Change Higher than Expected (i.e. 'Positive Surprise')	Interest Rate Change Lower than Expected (i.e. 'Negative Surprise')
	PLN/GBP foreign exchange rate: Full sample					
(1)	Full sample: 1 - 4544	-0.001742 (0.001672)	0.000606 (0.000949)	0.000441 (0.000949)	0.000792 (0.002972)	-0.002033 (0.002056)
	PLN/GBP foreign exchange rate: 1st sub-sample					
(1)	1st sub-sample: 1 - 2272	-0.002643 (0.002130)	0.000451 (0.001244)	-0.000322 (0.001130)	-0.000610 (0.005530)	-0.001732 (0.002835)
	PLN/GBP foreign exchange rate: 2nd sub-sample					
(1)	2nd sub-sample: 2273 - 4544	0.003068 (0.004575)	0.000780 (0.001503)	0.002779 (0.001795)	0.008528 (0.019250)	-0.002439 (0.004621)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the mean equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

Table 5. Estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1):

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \xi_t$$

from the GARCH model (1) - (2) of the PLN/CHF foreign exchange rate returns.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards	Interest Rate Change the same as Expected	Interest Rate Change Higher than Expected (i.e. 'Positive Surprise')	Interest Rate Change Lower than Expected (i.e. 'Negative Surprise')
	PLN/CHF foreign exchange rate: Full sample					
(1)	Full sample: 1 - 4544	-0.002543 ** (0.001262)	-0.000692 (0.001034)	-0.001340 (0.000862)	-0.000499 (0.002390)	-0.002088 (0.002514)
	PLN/CHF foreign exchange rate: 1st sub-sample					
(1)	1st sub-sample: 1 - 2272	-0.003174 ** (0.001597)	-0.000736 (0.001194)	-0.001467 (0.001262)	-0.001671 (0.015134)	-0.001780 (0.004656)
	PLN/CHF foreign exchange rate: 2nd sub-sample					
(1)	2nd sub-sample: 2273 - 4544	-0.002425 (0.003147)	-0.002497 (0.002880)	-0.001339 (0.003261)	-0.002455 (0.010029)	-0.002063 (0.002689)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the mean equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

Table 6. Estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1):

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \xi_t$$

from the GARCH model (1) - (2) of the PLN/JPY foreign exchange rate returns.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards	Interest Rate Change the same as Expected	Interest Rate Change Higher than Expected (i.e. 'Positive Surprise')	Interest Rate Change Lower than Expected (i.e. 'Negative Surprise')
	PLN/JPY foreign exchange rate: Full sample					
(1)	Full sample: 1 - 4544	-0.000101 (0.001647)	-0.000937 (0.001401)	-0.001249 (0.001682)	0.001291 (0.002243)	-0.000604 (0.002132)
	PLN/JPY foreign exchange rate: 1st sub-sample					
(1)	1st sub-sample: 1 - 2272	0.000782 (0.001420)	-0.001731 (0.001734)	-0.002082 (0.002300)	0.001738 (0.002114)	0.000211 (0.002709)
	PLN/JPY foreign exchange rate: 2nd sub-sample					
(1)	2nd sub-sample: 2273 - 4544	-0.005339 (0.008403)	0.001980 (0.002450)	0.002133 (0.003000)	-0.002613 (0.020788)	-0.001786 (0.004833)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the mean equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

5.1.2. Stock Market Models

Tables 7-9 show the estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1) from the GARCH model (1) - (2) of the WIG, WIG20 and sWIG80 indices.

The patterns of results are similar to the estimates from the foreign exchange rates models, i.e. in case of the WIG and WIG20 indices there is a clear dominance of statistically significant results in the first sub-period.

The response of the WIG and WIG20 stock market indices is also again evident for the interest rate changing upwards, while there is no statistical significance in case of the interest rates changing downwards, which indicates an asymmetric nature of the stock market reactions to the direction of the interest rates movements.

In case of the small stocks index sWIG80, the responses were not statistically significant to any of the announcements.

Table 7. Estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1):

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \xi_t$$

from the GARCH model (1) - (2) of the WIG index.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards	Interest Rate Change the same as Expected	Interest Rate Change Higher than Expected (i.e. 'Positive Surprise')	Interest Rate Change Lower than Expected (i.e. 'Negative Surprise')
	WIG index: Full sample					
(1)	Full sample: 1 - 4544	-0.005315 ** (0.002406)	-0.001435 (0.001349)	-0.002790 ** (0.001383)	-0.007626 ** (0.003110)	0.001688 (0.003081)
	WIG index: 1st sub-sample					
(1)	1st sub-sample: 1 - 2272	-0.007936 *** (0.002036)	-0.001521 (0.001481)	-0.001590 (0.001718)	-0.011296 *** (0.001814)	-0.000327 (0.002985)
	WIG index: 2nd sub-sample					
(1)	2nd sub-sample: 2273 - 4544	-0.004477 (0.005139)	-0.001252 (0.002311)	-0.002797 * (0.001613)	-0.005156 (0.006122)	0.003729 (0.003172)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the mean equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

Table 8. Estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1):

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \xi_t$$

from the GARCH model (1) - (2) of the WIG20 index.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards	Interest Rate Change the same as Expected	Interest Rate Change Higher than Expected (i.e. 'Positive Surprise')	Interest Rate Change Lower than Expected (i.e. 'Negative Surprise')
	WIG20 index: Full sample					
(1)	Full sample: 1 - 4544	-0.005651 * (0.003015)	-0.002074 (0.001707)	-0.003354 (0.002159)	-0.007738 *** (0.002727)	0.001617 (0.002341)
	WIG20 index: 1st sub-sample					
(1)	1st sub-sample: 1 - 2272	-0.007703 *** (0.002305)	-0.003219 (0.001957)	-0.001736 (0.002625)	-0.013038 *** (0.001761)	-0.001572 (0.004056)
	WIG20 index: 2nd sub-sample					
(1)	2nd sub-sample: 2273 - 4544	-0.004424 (0.002869)	-0.000612 (0.002750)	-0.004486 (0.003640)	-0.005767 (0.014936)	0.005258 (0.005865)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the mean equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

Table 9. Estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1):

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \xi_t$$

from the GARCH model (1) - (2) of the sWIG80 index.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards	Interest Rate Change the same as Expected	Interest Rate Change Higher than Expected (i.e. 'Positive Surprise')	Interest Rate Change Lower than Expected (i.e. 'Negative Surprise')
	sWIG80 index: Full sample					
(1)	Full sample: 1 - 4544	-0.000358 (0.002951)	0.000184 (0.001105)	9.66×10^{-5} (0.001252)	-0.000430 (0.003838)	0.000173 (0.001976)
	sWIG80 index: 1st sub-sample					
(1)	1st sub-sample: 1 - 2272	-0.000165 (0.003549)	0.000754 (0.001239)	0.002027 (0.001411)	-0.000342 (0.003227)	-0.002154 (0.002355)
	sWIG80 index: 2nd sub-sample					
(1)	2nd sub-sample: 2273 - 4544	-0.000594 (0.003720)	-0.000907 (0.002042)	-0.002658 (0.001982)	-0.001580 (0.010244)	0.004175 (0.002688)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the mean equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

5.1.3. Bonds Market Models

Tables 10-12 present the estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1) from the GARCH model (1) - (2) of the 1-year bond, 2-year bond and 5-year bond.

As in case of the foreign exchange market and the stock market, the results are more often significant in the first sub-sample rather than in the second sub-sample, which confirms the finding about the weakening effect of markets reactions to the NBP interest rates announcements over time when the interest rates in Poland were evolving from high levels to low levels.

Tables 10-12 document also an asymmetric response to the direction of the interest rates movements in the Polish bonds market, however it is evidently stronger in case of interest rates changing downwards rather than upwards.

Moreover, the sensitivity of bonds market seems to be higher when interest rate change was lower than expected (i.e. when there was a ‘negative surprise‘) than when the interest rate change was higher than expected (i.e. when there was a ‘positive surprise‘).

Table 10. Estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1):

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \xi_t$$

from the GARCH model (1) - (2) of the 1-year bond.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards	Interest Rate Change the same as Expected	Interest Rate Change Higher than Expected (i.e. 'Positive Surprise')	Interest Rate Change Lower than Expected (i.e. 'Negative Surprise')
	1-year bond: Full sample					
(1)	Full sample: 1 - 4544	0.002016 (0.001386)	-0.007398 *** (0.002471)	-0.002131 (0.002890)	0.006661 (0.008445)	-0.014140 *** (0.003331)
	1-year bond: 1st sub-sample					
(1)	1st sub-sample: 1 - 2272	0.002281 (0.001781)	-0.008107 *** (0.002034)	-0.004958 * (0.002654)	0.006224 (0.006076)	-0.011408 *** (0.002907)
	1-year bond: 2nd sub-sample					
(1)	2nd sub-sample: 2273 - 4544	0.003353 (0.021368)	-0.003224 (0.003489)	0.005508 (0.007151)	0.007760 (0.025492)	-0.022327 *** (0.006954)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the mean equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

Table 11. Estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1):

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \xi_t$$

from the GARCH model (1) - (2) of the 2-years bond.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards	Interest Rate Change the same as Expected	Interest Rate Change Higher than Expected (i.e. 'Positive Surprise')	Interest Rate Change Lower than Expected (i.e. 'Negative Surprise')
	2-years bond: Full sample					
(1)	Full sample: 1 - 4544	0.001826 (0.001196)	-0.004657 *** (0.001149)	-0.003288 ** (0.001662)	0.014343 *** (0.002173)	-0.006598 *** (0.001726)
	2-years bond: 1st sub-sample					
(1)	1st sub-sample: 1 - 2272	0.002228 (0.002090)	-0.003628 ** (0.001482)	-0.001778 (0.001638)	0.016724 *** (0.004601)	-0.003521 (0.004793)
	2-years bond: 2nd sub-sample					
(1)	2nd sub-sample: 2273 - 4544	-0.000679 (0.002665)	-0.002895 (0.002198)	0.001252 (0.006745)	0.007983 (0.015821)	-0.017402 *** (0.001719)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the mean equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

Table 12. Estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1):

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \xi_t$$

from the GARCH model (1) - (2) of the 5-years bond.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards	Interest Rate Change the same as Expected	Interest Rate Change Higher than Expected (i.e. 'Positive Surprise')	Interest Rate Change Lower than Expected (i.e. 'Negative Surprise')
	5-years bond: Full sample					
(1)	Full sample: 1 - 4544	0.000278 (0.002029)	-0.004888 *** (0.001731)	-0.004086 ** (0.001648)	0.006078 (0.004014)	-0.003456 (0.002412)
	5-years bond: 1st sub-sample					
(1)	1st sub-sample: 1 - 2272	0.003478 * (0.002056)	-0.004629 ** (0.001841)	-0.002690 * (0.001497)	0.009027 *** (0.002836)	-0.003039 (0.002113)
	5-years bond: 2nd sub-sample					
(1)	2nd sub-sample: 2273 - 4544	-0.005009 (0.003212)	-0.004152 (0.004810)	-0.005862 * (0.003437)	-0.000573 (0.015356)	-0.022844 *** (0.006557)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the mean equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

5.1.4. Derivatives Market Models

Finally, Table 13 shows the estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1) from the GARCH model (1) - (2) of the WIG20 index futures.

The pattern of results from the WIG20 index futures model is consistent with the findings for other market segments, in particular for the stock market and the underlying WIG20 index.

In the full sample period, the response of the WIG20 index futures was again evident for the interest rate changing upwards, while there is no statistical significance in case of the interest rates changing downwards, which indicates again a similar asymmetric nature of the futures market reactions to the direction of the interest rates movements as in case of the underlying stock index. There is also a statistically significant estimation result for the dummy variable capturing the interest rate change which was higher than expected by the market (i.e. 'positive surprise'), while no significance was detected when interest rate change was lower than expected (i.e. 'negative surprise').

Moreover, Table 13 depicts the same patterns of results across both sub-samples, i.e. there is a very clear dominance of statistically significant results in the first sub-period and no statistically significant reactions were detected in the second sub-period.

Table 13. Estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1):

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \xi_t$$

from the GARCH model (1) - (2) of the WIG20 index futures.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards	Interest Rate Change the same as Expected	Interest Rate Change Higher than Expected (i.e. 'Positive Surprise')	Interest Rate Change Lower than Expected (i.e. 'Negative Surprise')
	WIG20 index futures: Full sample					
(1)	Full sample: 1 - 4544	-0.005610 ** (0.002843)	-0.003584 (0.002257)	-0.003735 * (0.002132)	-0.010160 ** (0.004261)	-0.001053 (0.004561)
	WIG20 index futures: 1st sub-sample					
(1)	1st sub-sample: 1 - 2272	-0.008915 *** (0.002391)	-0.006048 *** (0.002156)	-0.004484 * (0.002315)	-0.017246 *** (0.002409)	-0.004668 (0.003811)
	WIG20 index futures: 2nd sub-sample					
(1)	2nd sub-sample: 2273 - 4544	-0.004717 (0.005956)	0.001092 (0.005538)	-0.003906 (0.004232)	-0.003163 (0.042877)	0.009738 (0.008416)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the mean equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

5.2. Effects in the Conditional Variance Equation

In the following sections, we focus now on the analysis of the interest rates announcements effects in the conditional variance equations.

5.2.1. Foreign Exchange Market Models

Tables 14-18 present the estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the conditional variance equation (2) from the GARCH model (1) - (2) of the five analyzed foreign exchange rate returns.

The estimated parameters, which are statistically significant, are both positive and negative, which provides mixed evidence about the nature of the impact of the NBP interest rates announcements on the foreign exchange market in terms of any possible stabilizing or destabilizing effects.

Tables 14-18 also show that there is a marginally higher number of statistically significant results in the first sub-period relative to the second sub-period (i.e. 11 *versus* 10 cases).

Table 14. Estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the conditional variance equation (2):

$$h_t^i = \beta_0 + \beta_1 \cdot \xi_{t-1}^2 + \beta_2 \cdot \sigma_{t-1}^2 + \beta_3 \cdot DUM_t$$

from the GARCH model (1) - (2) of the PLN/EUR foreign exchange rate returns.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards	Interest Rate Change the same as Expected	Interest Rate Change Higher than Expected (i.e. 'Positive Surprise')	Interest Rate Change Lower than Expected (i.e. 'Negative Surprise')
	PLN/EUR foreign exchange rate: Full sample					
(2)	Full sample: 1 - 4544	1.83×10^6 (2.18×10^6)	6.13×10^6 *** (1.93×10^6)	1.98×10^6 (2.16×10^6)	5.82×10^6 (4.43×10^6)	1.07×10^5 *** (2.52×10^6)
	PLN/EUR foreign exchange rate: 1st sub-sample					
(2)	1st sub-sample: 1 - 2272	-3.17×10^5 *** (6.33×10^7)	5.12×10^6 (9.85×10^6)	0.035124 (0.112792)	-0.072514 (0.265569)	0.849114 *** (0.121262)
	PLN/EUR foreign exchange rate: 2nd sub-sample					
(2)	2nd sub-sample: 2273 - 4544	7.33×10^6 (5.30×10^6)	-6.41×10^7 (2.39×10^6)	2.29×10^6 (4.14×10^6)	1.77×10^5 (1.10×10^5)	-3.98×10^6 (2.55×10^6)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the conditional variance equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

Table 15. Estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the conditional variance equation (2):

$$h_t^i = \beta_0 + \beta_1 \cdot \xi_{t-1}^2 + \beta_2 \cdot \sigma_{t-1}^2 + \beta_3 \cdot DUM_t$$

from the GARCH model (1) - (2) of the PLN/USD foreign exchange rate returns.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards	Interest Rate Change the same as Expected	Interest Rate Change Higher than Expected (i.e. 'Positive Surprise')	Interest Rate Change Lower than Expected (i.e. 'Negative Surprise')
	PLN/USD foreign exchange rate: Full sample					
(2)	Full sample: 1 - 4544	4.33×10^6 (5.15×10^6)	8.76×10^6 *** (2.19×10^6)	4.32×10^6 (3.41×10^6)	2.20×10^6 (7.73×10^6)	1.75×10^5 *** (2.99×10^6)
	PLN/USD foreign exchange rate: 1st sub-sample					
(2)	1st sub-sample: 1 - 2272	-9.48×10^6 (5.86×10^6)	9.27×10^6 ** (3.93×10^6)	-2.04×10^7 (4.44×10^6)	-5.94×10^6 (9.07×10^6)	3.05×10^5 *** (5.96×10^6)
	PLN/USD foreign exchange rate: 2nd sub-sample					
(2)	2nd sub-sample: 2273 - 4544	3.80×10^5 ** (1.73x10/5)	2.63×10^6 (4.11×10^6)	1.32×10^5 ** (6.36×10^6)	6.45×10^5 * (3.61×10^5)	-9.66×10^6 * (5.41×10^6)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the conditional variance equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

Table 16. Estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the conditional variance equation (2):

$$h_t^i = \beta_0 + \beta_1 \cdot \xi_{t-1}^2 + \beta_2 \cdot \sigma_{t-1}^2 + \beta_3 \cdot DUM_t$$

from the GARCH model (1) - (2) of the PLN/GBP foreign exchange rate returns.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards	Interest Rate Change the same as Expected	Interest Rate Change Higher than Expected (i.e. 'Positive Surprise')	Interest Rate Change Lower than Expected (i.e. 'Negative Surprise')
	PLN/GBP foreign exchange rate: Full sample					
(2)	Full sample: 1 - 4544	5.66×10^6 (3.75×10^6)	6.04×10^6 ** (2.61×10^6)	5.43×10^6 * (3.12×10^6)	7.57×10^6 (5.15×10^6)	6.45×10^6 * (3.63×10^6)
	PLN/GBP foreign exchange rate: 1st sub-sample					
(2)	1st sub-sample: 1 - 2272	1.36×10^6 (4.41×10^6)	1.12×10^5 ** (5.18×10^6)	4.09×10^6 (4.43×10^6)	2.33×10^6 (5.51×10^6)	2.36×10^5 *** (7.07×10^6)
	PLN/GBP foreign exchange rate: 2nd sub-sample					
(2)	2nd sub-sample: 2273 - 4544	2.09×10^5 ** (8.29×10^6)	-4.79×10^7 (2.84×10^6)	8.62×10^6 ** (4.08×10^6)	4.13×10^5 ** (1.65×10^5)	-1.57×10^5 *** (3.42×10^6)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the conditional variance equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

Table 17. Estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the conditional variance equation (2):

$$h_t^i = \beta_0 + \beta_1 \cdot \xi_{t-1}^2 + \beta_2 \cdot \sigma_{t-1}^2 + \beta_3 \cdot DUM_t$$

from the GARCH model (1) - (2) of the PLN/CHF foreign exchange rate returns.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards	Interest Rate Change the same as Expected	Interest Rate Change Higher than Expected (i.e. 'Positive Surprise')	Interest Rate Change Lower than Expected (i.e. 'Negative Surprise')
	PLN/CHF foreign exchange rate: Full sample					
(2)	Full sample: 1 - 4544	-6.34×10^6 * (3.61×10^6)	-2.27×10^6 (1.97×10^6)	-8.54×10^6 ** (3.48×10^6)	-1.68×10^6 (5.59×10^6)	7.92×10^6 *** (2.76×10^6)
	PLN/CHF foreign exchange rate: 1st sub-sample					
(2)	1st sub-sample: 1 - 2272	-2.27×10^5 *** (6.38×10^6)	-4.15×10^6 (1.25×10^5)	5.82×10^7 (4.45×10^6)	-5.93×10^7 (4.96×10^6)	4.31×10^5 *** (5.89×10^6)
	PLN/CHF foreign exchange rate: 2nd sub-sample					
(2)	2nd sub-sample: 2273 - 4544	1.76×10^5 (8.60×10^5)	3.19×10^5 (2.86×10^5)	3.00×10^5 (3.36×10^5)	-4.72×10^6 (0.000201)	-5.91×10^5 *** (3.94×10^6)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the conditional variance equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

Table 18. Estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the conditional variance equation (2):

$$h_t^i = \beta_0 + \beta_1 \cdot \xi_{t-1}^2 + \beta_2 \cdot \sigma_{t-1}^2 + \beta_3 \cdot DUM_t$$

from the GARCH model (1) - (2) of the PLN/JPY foreign exchange rate returns.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards	Interest Rate Change the same as Expected	Interest Rate Change Higher than Expected (i.e. 'Positive Surprise')	Interest Rate Change Lower than Expected (i.e. 'Negative Surprise')
	PLN/JPY foreign exchange rate: Full sample					
(2)	Full sample: 1 - 4544	-6.38×10^6 (8.08×10^6)	9.83×10^6 ** (4.28×10^6)	3.26×10^6 (4.94×10^6)	4.36×10^6 (1.17×10^5)	1.46×10^5 ** (5.90×10^6)
	PLN/JPY foreign exchange rate: 1st sub-sample					
(2)	1st sub-sample: 1 - 2272	-1.46×10^5 * (8.02×10^6)	1.08×10^5 ** (5.51×10^6)	-2.76×10^6 (5.10×10^6)	-1.06×10^6 (1.19×10^5)	2.78×10^5 *** (8.71×10^6)
	PLN/JPY foreign exchange rate: 2nd sub-sample					
(2)	2nd sub-sample: 2273 - 4544	4.58×10^5 * (2.68×10^5)	4.67×10^6 (1.32×10^5)	2.57×10^5 (1.79×10^5)	5.82×10^5 (6.24×10^5)	-1.25×10^5 (1.23×10^5)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the conditional variance equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

5.2.2. Stock Market Models

Tables 19-21 present the estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the conditional variance equation (2) from the GARCH model (1) - (2) of the three investigated stock market indices.

The estimated parameters, which are statistically significant, are always negative in all cases, which leads to the conclusion that the NBP interest rates announcements had a calming (i.e. stabilizing) effect on the stock market in Poland (in the whole sample period and also consistently in both sub-periods).

In terms of the differences of the results across the sub-samples, Tables 19-21 document a dominance of statistically significant estimates in the first sub-period relative to the second sub-period (i.e. 9 *versus* 5 cases).

Table 19. Estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the conditional variance equation (2):

$$h_t^i = \beta_0 + \beta_1 \cdot \xi_{t-1}^2 + \beta_2 \cdot \sigma_{t-1}^2 + \beta_3 \cdot DUM_t$$

from the GARCH model (1) - (2) of the WIG index.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards	Interest Rate Change the same as Expected	Interest Rate Change Higher than Expected (i.e. 'Positive Surprise')	Interest Rate Change Lower than Expected (i.e. 'Negative Surprise')
	WIG index: Full sample					
(2)	Full sample: 1 - 4544	-2.19×10^5 *** (8.04×10^6)	-3.98×10^6 (6.12×10^6)	-4.71×10^6 (6.63×10^6)	-2.71×10^5 *** (8.65×10^6)	-8.82×10^6 (1.03×10^5)
	WIG index: 1st sub-sample					
(2)	1st sub-sample: 1 - 2272	-5.30×10^5 *** (1.44×10^5)	-2.07×10^5 * (1.10×10^5)	-1.28×10^5 (1.37×10^5)	-6.17×10^5 *** (1.70×10^5)	-4.24×10^5 ** (1.88×10^5)
	WIG index: 2nd sub-sample					
(2)	2nd sub-sample: 2273 - 4544	-1.57×10^5 (1.20×10^5)	-8.36×10^6 (7.56×10^6)	-4.32×10^5 *** (1.48×10^5)	-8.07×10^5 *** (4.33×10^6)	-4.15×10^5 (6.39×10^5)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the conditional variance equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

Table 20. Estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the conditional variance equation (2):

$$h_t^i = \beta_0 + \beta_1 \cdot \xi_{t-1}^2 + \beta_2 \cdot \sigma_{t-1}^2 + \beta_3 \cdot DUM_t$$

from the GARCH model (1) - (2) of the WIG20 index.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards	Interest Rate Change the same as Expected	Interest Rate Change Higher than Expected (i.e. 'Positive Surprise')	Interest Rate Change Lower than Expected (i.e. 'Negative Surprise')
	WIG20 index: Full sample					
(2)	Full sample: 1 - 4544	-1.41×10^5 ** (6.50×10^6)	-1.16×10^6 (4.67×10^6)	4.04×10^5 (2.84×10^5)	-7.25×10^5 ** (3.55×10^5)	-4.71×10^5 * (2.42×10^5)
	WIG20 index: 1st sub-sample					
(2)	1st sub-sample: 1 - 2272	-5.83×10^5 *** (1.66×10^5)	-1.59×10^5 (1.60×10^5)	3.71×10^5 (4.00×10^5)	-0.000110 *** (3.08×10^5)	-7.60×10^5 (4.80×10^5)
	WIG20 index: 2nd sub-sample					
(2)	2nd sub-sample: 2273 - 4544	-6.28×10^5 *** (5.85×10^6)	-2.41×10^5 (2.70×10^5)	-7.98×10^6 (5.48×10^6)	-1.62×10^5 ** (8.18×10^6)	-2.44×10^5 *** (8.27×10^6)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the conditional variance equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

Table 21. Estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the conditional variance equation (2):

$$h_t^i = \beta_0 + \beta_1 \cdot \xi_{t-1}^2 + \beta_2 \cdot \sigma_{t-1}^2 + \beta_3 \cdot DUM_t$$

from the GARCH model (1) - (2) of the sWIG80 index.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards	Interest Rate Change the same as Expected	Interest Rate Change Higher than Expected (i.e. 'Positive Surprise')	Interest Rate Change Lower than Expected (i.e. 'Negative Surprise')
	sWIG80 index: Full sample					
(2)	Full sample: 1 - 4544	-6.56x10^7 (7.95x10^6)	-1.55x10^6 (3.76x10^6)	-2.35x10^6 (3.82x10^6)	1.35x10^5 (1.77x10^5)	-5.07x10^6 (9.17x10^6)
	sWIG80 index: 1st sub-sample					
(2)	1st sub-sample: 1 - 2272	-2.08x10^5 (1.50x10^5)	-2.69x10^5 *** (5.27x10^6)	-2.52x10^5 *** (6.12x10^6)	-2.42x10^5 (2.18x10^5)	-3.56x10^5 *** (1.15x10^5)
	sWIG80 index: 2nd sub-sample					
(2)	2nd sub-sample: 2273 - 4544	8.37x10^7 (1.11x10^5)	2.20x10^6 (7.31x10^6)	-7.68x10^6 (5.86x10^6)	4.28x10^5 (4.77x10^5)	2.73x10^6 (1.35x10^5)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the conditional variance equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

5.2.3. Bonds Market Models

Tables 22-24 present the estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the conditional variance equation (2) from the GARCH model (1) - (2) of the three analyzed bonds.

As in case of the foreign exchange market models, the estimated parameters, which are statistically significant, are both positive and negative, which provides mixed evidence as well about the nature of the impact of the NBP interest rates announcements on the bonds market in terms of any possible stabilizing or destabilizing effects.

In the first sub-period there is a higher number of statistically significant results in comparison with the second sub-period (i.e. 5 *versus* 3 cases), which is consistent with majority of previous findings from other models and from other market segments.

Table 22. Estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the conditional variance equation (2):

$$h_t^i = \beta_0 + \beta_1 \cdot \xi_{t-1}^2 + \beta_2 \cdot \sigma_{t-1}^2 + \beta_3 \cdot DUM_t$$

from the GARCH model (1) - (2) of the 1-year bond.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards	Interest Rate Change the same as Expected	Interest Rate Change Higher than Expected (i.e. 'Positive Surprise')	Interest Rate Change Lower than Expected (i.e. 'Negative Surprise')
	1-year bond: Full sample					
(2)	Full sample: 1 - 4544	-0.000137 *** ($8.96\text{x}10^6$)	$9.37\text{x}10^5$ ** ($4.08\text{x}10^5$)	$-7.86\text{x}10^7$ ($5.07\text{x}10^5$)	$-4.52\text{x}10^6$ (0.000222)	$2.40\text{x}10^7$ ($4.75\text{x}10^5$)
	1-year bond: 1st sub-sample					
(2)	1st sub-sample: 1 - 2272	$-6.08\text{x}10^5$ *** ($1.47\text{x}10^5$)	$3.97\text{x}10^5$ ($3.56\text{x}10^5$)	$-9.37\text{x}10^8$ ($3.16\text{x}10^5$)	$-1.99\text{x}10^6$ (0.000209)	$2.79\text{x}10^7$ ($4.59\text{x}10^5$)
	1-year bond: 2nd sub-sample					
(2)	2nd sub-sample: 2273 - 4544	$-5.06\text{x}10^6$ (0.000269)	$5.17\text{x}10^7$ ($4.70\text{x}10^5$)	$-1.32\text{x}10^6$ (0.000203)	$-5.50\text{x}10^6$ (0.000474)	$1.64\text{x}10^6$ (0.000185)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the conditional variance equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

Table 23. Estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the conditional variance equation (2):

$$h_t^i = \beta_0 + \beta_1 \cdot \xi_{t-1}^2 + \beta_2 \cdot \sigma_{t-1}^2 + \beta_3 \cdot DUM_t$$

from the GARCH model (1) - (2) of the 2-years bond.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards	Interest Rate Change the same as Expected	Interest Rate Change Higher than Expected (i.e. 'Positive Surprise')	Interest Rate Change Lower than Expected (i.e. 'Negative Surprise')
	2-years bond: Full sample					
(2)	Full sample: 1 - 4544	-1.96×10^5 *** (4.10×10^6)	1.21×10^5 ** (5.08×10^6)	2.73×10^5 *** (6.55×10^6)	-1.66×10^5 * (1.01×10^5)	6.84×10^6 (7.69×10^6)
	2-years bond: 1st sub-sample					
(2)	1st sub-sample: 1 - 2272	1.73×10^5 ** (6.87×10^6)	3.44×10^5 *** (6.29×10^6)	9.88×10^6 (8.82×10^6)	0.000113 (8.30×10^5)	0.000166 *** (4.29×10^5)
	2-years bond: 2nd sub-sample					
(2)	2nd sub-sample: 2273 - 4544	-4.57×10^5 ** (1.94×10^5)	1.36×10^5 (2.69×10^5)	8.12×10^5 (0.000175)	-0.000169 (0.000137)	-0.000129 *** (1.35×10^5)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the conditional variance equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

Table 24. Estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the conditional variance equation (2):

$$h_t^i = \beta_0 + \beta_1 \cdot \xi_{t-1}^2 + \beta_2 \cdot \sigma_{t-1}^2 + \beta_3 \cdot DUM_t$$

from the GARCH model (1) - (2) of the 5-years bond.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards	Interest Rate Change the same as Expected	Interest Rate Change Higher than Expected (i.e. 'Positive Surprise')	Interest Rate Change Lower than Expected (i.e. 'Negative Surprise')
	5-years bond: Full sample					
(2)	Full sample: 1 - 4544	5.72×10^6 (1.92×10^5)	8.59×10^5 ** (3.66×10^5)	3.97×10^5 *** (7.72×10^6)	5.95×10^5 *** (1.71×10^5)	2.82×10^5 ** (1.27×10^5)
	5-years bond: 1st sub-sample					
(2)	1st sub-sample: 1 - 2272	1.54×10^6 (4.13×10^5)	6.19×10^5 * (3.19×10^5)	0.176696 (0.149795)	-0.020535 (0.323029)	0.143631 (0.206580)
	5-years bond: 2nd sub-sample					
(2)	2nd sub-sample: 2273 - 4544	-5.85×10^6 (3.33×10^5)	0.000239 (0.000222)	0.544164 ** (0.227422)	0.536239 (0.696972)	-0.276744 (0.265930)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the conditional variance equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

5.2.4. Derivatives Market Models

Finally, Table 25 illustrates the estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the conditional variance equation (2) from the GARCH model (1) - (2) of the WIG20 index futures.

The estimated parameters, which are statistically significant, are almost always negative (except for only two cases), which supports the previous conclusion that the NBP interest rates announcements had a calming (i.e. stabilizing) effect on the stock market in Poland.

In terms of the differences of the results across the sub-samples, Table 25 evidences once again a strong dominance of statistically significant estimates in the first sub-period relative to the second sub-period (i.e. 5 *versus* 1 cases). Therefore, the pattern of the estimated parameters from the WIG20 index futures model is generally consistent with the previous overall findings for the stock market and for other market segments.

Table 25. Estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the conditional variance equation (2):

$$h_t^i = \beta_0 + \beta_1 \cdot \xi_{t-1}^2 + \beta_2 \cdot \sigma_{t-1}^2 + \beta_3 \cdot DUM_t$$

from the GARCH model (1) - (2) of the WIG20 index futures.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards	Interest Rate Change the same as Expected	Interest Rate Change Higher than Expected (i.e. 'Positive Surprise')	Interest Rate Change Lower than Expected (i.e. 'Negative Surprise')
	WIG20 index futures: Full sample					
(2)	Full sample: 1 - 4544	-2.06x10^5 * (1.19x10^5)	1.08x10^5 * (6.15x10^6)	-7.65x10^7 (7.30x10^6)	-2.28x10^5 (1.69x10^5)	1.14x10^5 (1.69x10^5)
	WIG20 index futures: 1st sub-sample					
(2)	1st sub-sample: 1 - 2272	-7.16x10^5 *** (1.93x10^5)	-4.30x10^5 ** (1.74x10^5)	-4.03x10^5 ** (1.94x10^5)	-0.000106*** (1.72x10^5)	-7.50x10^5 *** (2.67x10^5)
	WIG20 index futures: 2nd sub-sample					
(2)	2nd sub-sample: 2273 - 4544	-1.86x10^5 (1.46x10^5)	1.81x10^5 *** (6.27x10^6)	0.163694 (0.102408)	0.052208 (0.509322)	0.288024 (0.208465)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the conditional variance equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

5.3. Robustness Analysis

We further performed a number of different robustness checks of the results presented so far, such as:

- Analysis of models with sample division into two alternative sub-periods using different other division dates
- Analysis of models with sample division into three sub-periods
- Analysis of models with sample division into five sub-periods
- Analysis of models based on shorter sample starting from the year 2004
- Analysis of alternative specifications of models with additional control variables.

Due to space considerations, below we discuss only some representative examples, which illustrate the overall findings.

5.3.1. Results for Alternative Sub-periods with Different Division Dates

In this section, we discuss the key findings from Tables 26-31, which present examples of the results for alternative sub-periods with different division dates from the PLN/EUR foreign exchange rate models, WIG index models and 1-year bond models.

Table 26 shows that in the original two sub-samples (for the observations: 1 – 2272 and 2273 – 4544) the estimates of dummy variable INTRATE_UP for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1) from the GARCH model (1)

- (2) of the PLN/EUR foreign exchange rate returns are: -0.003309 (significant at 1% level) and -0.001490 (not significant), respectively. However, the estimates in the alternative sub-samples: 1 – 1800, 1 – 2000, 1 – 2200, 1 – 2400, 1 – 2600, 1 – 2800 (for the first sub-period) and 2001 – 4544, 2201 – 4544, 2401 – 4544, 2601 – 4544, 2801 – 4544, 3001 – 4544 (for the second sub-period) are remarkably similar in terms of the value of the estimated parameters and the conclusions about their statistical significance.

Table 27 further depicts a similar effect for the variable INTRATE_DOWN, where the original estimate is also robust to the alternative sub-sample periods choice.

Analysis of the estimates in the alternative sub-samples for other market segments reveals the same picture.

Tables 28-29 show that for the WIG index the estimated parameters are very similar in terms of their value and also from the point of view of the conclusions about their statistical significance.

Likewise, the results for the 1-year bond presented in Tables 30-31 are remarkably consistent too across all the alternative sub-samples.

Therefore, we can conclude that our findings are robust with respect to different alternative division dates around the middle of our entire sample period.

Table 26. Alternative divisions into samples: estimates of dummy variable INTRATE_UP for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1):

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \xi_t$$

from the GARCH model (1) - (2) of the PLN/EUR foreign exchange rate returns.

PLN/EUR foreign exchange rate: 1st sub-sample						
Original sub-sample: 1 – 2272	**Sub-sample: 1 – 1800**	**Sub-sample: 1 – 2000**	**Sub-sample: 1 – 2200**	**Sub-sample: 1 – 2400**	**Sub-sample: 1 – 2600**	**Sub-sample: 1 – 2800**
-0.003309 *** (0.000623)	-0.002716 *** (0.000366)	-0.002803 * (0.001524)	-0.002843 ** (0.001427)	-0.002847 * (0.001500)	-0.002834 ** (0.001429)	-0.002916 ** (0.001363)
PLN/EUR foreign exchange rate: 2nd sub-sample						
Original sub-sample: 2273 – 4544	**Sub-sample: 2001 – 4544**	**Sub-sample: 2201 – 4544**	**Sub-sample: 2401 – 4544**	**Sub-sample: 2601 – 4544**	**Sub-sample: 2801 – 4544**	**Sub-sample: 3001 – 4544**
-0.001490 (0.001686)	-0.001909 (0.001572)	-0.001454 (0.001697)	-0.001460 (0.001720)	-0.001479 (0.001719)	-0.000587 (0.002287)	0.008931 (0.715499)

Notes: (1) Values of the standard errors in the brackets. (2) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

Table 27. Alternative divisions into samples: estimates of dummy variable INTRATE_DOWN for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1):

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \xi_t$$

from the GARCH model (1) - (2) of the PLN/EUR foreign exchange rate returns.

PLN/EUR foreign exchange rate: 1st sub-sample						
Original sub-sample: 1 – 2272	**Sub-sample: 1 – 1800**	**Sub-sample: 1 – 2000**	**Sub-sample: 1 – 2200**	**Sub-sample: 1 – 2400**	**Sub-sample: 1 – 2600**	**Sub-sample: 1 – 2800**
-0.000299 (0.001326)	0.000673 (0.000909)	0.000701 (0.001598)	0.000555 (0.001558)	0.000558 (0.001517)	0.000590 (0.001552)	0.000590 (0.001561)
PLN/EUR foreign exchange rate: 2nd sub-sample						
Original sub-sample: 2273 – 4544	**Sub-sample: 2001 – 4544**	**Sub-sample: 2201 – 4544**	**Sub-sample: 2401 – 4544**	**Sub-sample: 2601 – 4544**	**Sub-sample: 2801 – 4544**	**Sub-sample: 3001 – 4544**
-0.000410 (0.001018)	-0.000412 (0.001027)	-0.000320 (0.001021)	-0.000266 (0.001021)	-0.000335 (0.001012)	-0.000587 (0.002287)	-0.000391 (0.001015)

Notes: (1) Values of the standard errors in the brackets. (2) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

Table 28. Alternative divisions into samples: estimates of dummy variable INTRATE_UP for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1):

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \xi_t$$

from the GARCH model (1) - (2) of the WIG index returns.

WIG index: 1st sub-sample						
Original sub-sample: 1 – 2272	**Sub-sample: 1 – 1800**	**Sub-sample: 1 – 2000**	**Sub-sample: 1 – 2200**	**Sub-sample: 1 – 2400**	**Sub-sample: 1 – 2600**	**Sub-sample: 1 – 2800**
-0.007936 *** (0.002036)	-0.010778 *** (0.001723)	-0.008494 *** (0.001938)	-0.007719 *** (0.002024)	-0.008100 *** (0.002035)	-0.008076 *** (0.001957)	-0.006195 *** (0.001778)
WIG index: 2nd sub-sample						
Original sub-sample: 2273 – 4544	**Sub-sample: 2001 – 4544**	**Sub-sample: 2201 – 4544**	**Sub-sample: 2401 – 4544**	**Sub-sample: 2601 – 4544**	**Sub-sample: 2801 – 4544**	**Sub-sample: 3001 – 4544**
-0.004477 (0.005139)	-0.004187 (0.005234)	-0.003048 (0.004798)	-0.004437 (0.004983)	-0.003775 (0.003080)	-0.003460 (0.017989)	-0.002268 (0.376319)

Notes: (1) Values of the standard errors in the brackets. (2) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

Table 29. Alternative divisions into samples: estimates of dummy variable INTRATE_DOWN for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1):

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \xi_t$$

from the GARCH model (1) - (2) of the WIG index returns.

WIG index: 1st sub-sample						
Original sub-sample: 1 – 2272	**Sub-sample: 1 – 1800**	**Sub-sample: 1 – 2000**	**Sub-sample: 1 – 2200**	**Sub-sample: 1 – 2400**	**Sub-sample: 1 – 2600**	**Sub-sample: 1 – 2800**
-0.001521 (0.001481)	-0.002137 (0.001582)	-0.002007 (0.001540)	-0.001854 (0.001507)	-0.001375 (0.001473)	-0.001253 (0.001470)	-0.001440 (0.001538)
WIG index: 2nd sub-sample						
Original sub-sample: 2273 – 4544	**Sub-sample: 2001 – 4544**	**Sub-sample: 2201 – 4544**	**Sub-sample: 2401 – 4544**	**Sub-sample: 2601 – 4544**	**Sub-sample: 2801 – 4544**	**Sub-sample: 3001 – 4544**
-0.001252 (0.002311)	-0.001017 (0.002178)	-0.001297 (0.003841)	-0.001414 (0.002287)	-7.16×10^{5} (0.002086)	0.000331 (0.000890)	-0.000738 (0.001027)

Notes: (1) Values of the standard errors in the brackets. (2) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

Table 30. Alternative divisions into samples: estimates of dummy variable INTRATE_UP for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1):

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \xi_t$$

from the GARCH model (1) - (2) of the 1-year bond.

1-year bond: 1st sub-sample						
Original sub-sample: 1 – 2272	**Sub-sample: 1 – 1800**	**Sub-sample: 1 – 2000**	**Sub-sample: 1 – 2200**	**Sub-sample: 1 – 2400**	**Sub-sample: 1 – 2600**	**Sub-sample: 1 – 2800**
0.002281 (0.001781)	0.001265 (0.001477)	0.002896 (0.001866)	0.002297 (0.001815)	0.002328 (0.001779)	0.002355 (0.001806)	0.001982 (0.001522)
1-year bond: 2nd sub-sample						
Original sub-sample: 2273 – 4544	**Sub-sample: 2001 – 4544**	**Sub-sample: 2201 – 4544**	**Sub-sample: 2401 – 4544**	**Sub-sample: 2601 – 4544**	**Sub-sample: 2801 – 4544**	**Sub-sample: 3001 – 4544**
0.003353 (0.021368)	0.002207 (0.018337)	0.003349 (0.021305)	0.003287 (0.022270)	0.000559 (0.001821)	0.005225 (0.027409)	0.014555 (28.72166)

Notes: (1) Values of the standard errors in the brackets. (2) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

Table 31. Alternative divisions into samples: estimates of dummy variable INTRATE_DOWN for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1):

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \xi_t$$

from the GARCH model (1) - (2) of the 1-year bond.

1-year bond: 1st sub-sample						
Original sub-sample: 1 – 2272	**Sub-sample: 1 – 1800**	**Sub-sample: 1 – 2000**	**Sub-sample: 1 – 2200**	**Sub-sample: 1 – 2400**	**Sub-sample: 1 – 2600**	**Sub-sample: 1 – 2800**
-0.008107 *** (0.002034)	-0.007237 *** (0.002313)	-0.007442 *** (0.002313)	-0.007814 *** (0.002154)	-0.008420 *** (0.001978)	-0.008491 *** (0.002007)	-0.008403 *** (0.001961)
1-year bond: 2nd sub-sample						
Original sub-sample: 2273 – 4544	**Sub-sample: 2001 – 4544**	**Sub-sample: 2201 – 4544**	**Sub-sample: 2401 – 4544**	**Sub-sample: 2601 – 4544**	**Sub-sample: 2801 – 4544**	**Sub-sample: 3001 – 4544**
-0.003224 (0.003489)	-0.006262 ** (0.003069)	-0.004770 (0.003327)	-0.001855 (0.003837)	-0.004068 (0.008388)	-0.001876 (0.004438)	-0.003037 (0.006280)

Notes: (1) Values of the standard errors in the brackets. (2) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

5.3.2. Results for Three Sub-periods

In this section, we conduct further robustness checks and we discuss the key findings from Tables 32-34, which illustrate some representative examples from the PLN/EUR foreign exchange rate, WIG index and 1-year bond models when the full sample period is now divided differently by distinguishing three sub-samples.

The estimated parameters in Table 32 for the PLN/EUR foreign exchange rate model show that the statistically significant estimates were found only in the first two sub-periods and they become insignificant in the third sub-period.

Similarly, the pattern of results in Tables 33 and 34 for the WIG index model and for the 1-year bond model confirms this effect.

Hence, we conclude that our findings are robust to the division of the whole sample into three sub-samples and they consistently depict the weakening effect of the analyzed reactions over time.

Table 32. Division into 3 sub-samples: estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1):

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \xi_t$$

from the GARCH model (1) - (2) of the PLN/EUR foreign exchange rate returns.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards
(1)	1st sub-sample: 1 - 1515	-0.002547 *** (0.000439)	0.000672 (0.000725)
(1)	2nd sub-sample: 1516 - 3029	-0.002514 ** (0.000999)	-0.002914 (0.011352)
(1)	3rd sub-sample: 3030 - 4544	0.008879 (0.434793)	-0.000395 (0.001021)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the mean equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

Table 33. Division into 3 sub-samples: estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1):

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \xi_t$$

from the GARCH model (1) - (2) of the WIG index returns.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards
(1)	1st sub-sample: 1 - 1515	-0.010970 *** (0.001799)	-0.002163 (0.001601)
(1)	2nd sub-sample: 1516 - 3029	-0.004338 *** (0.001489)	0.009178 (0.012552)
(1)	3rd sub-sample: 3030 - 4544	-0.003250 (0.124205)	-0.000478 (0.002522)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the mean equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

Table 34. Division into 3 sub-samples: estimates of dummy variables for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (1):

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \xi_t$$

from the GARCH model (1) - (2) of the 1-year bond.

Equation:	Sample:	Interest Rate Change Upwards	Interest Rate Change Downwards
(1)	1st sub-sample: 1 - 1515	0.000791 (0.001179)	-0.007067 *** (0.002328)
(1)	2nd sub-sample: 1516 - 3029	0.001086 (0.000890)	-0.019118 *** (0.001829)
(1)	3rd sub-sample: 3030 - 4544	0.016033 (0.640815)	-0.003925 (0.008376)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the mean equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

5.3.3. Results for Five Sub-periods

Further to the split of the entire sample period into three sub-samples, we also investigated the results when the division is made using five sub-samples.

This additional analysis is motivated by the fact that until the end of the year 2003, the NBP conducted its monetary policy according to the guidelines determined by the Monetary Policy Council, where the basic goal was defined as maintaining price stability and the NBP was expected to pursue direct inflation targeting. However, starting from the beginning of the year 2004 the continuous inflation target has been applied standing at 2.5% with a permissible fluctuation band of +/- 1 percentage point (meaning that every month the annual CPI should be as close as possible to 2.5%), which marks an important change in the monetary policy principles at this time point (see: www.nbp.pl).

After dividing our sample into five almost exactly equal sub-periods, we obtained the structure within which the old monetary policy rules functioning until the end of the year 2003 were applied in the period corresponding to the first sub-sample, while the new rules were implemented subsequently in the next four sub-periods. Such division of the entire sample allowed us, therefore, to investigate further whether the change of the monetary policy rules, which occurred at the beginning of the year 2004, had any impact on our results.

We performed the estimations in all five sub-samples, however the obtained results may not be considered as reliable due to the following two reasons:

First, in the initial sub-sample covering the first monetary policy period from August 2000 to December 2003 there was only one instance of interest rate changing upwards. Therefore, any estimates relying on just one such event are always inevitably dubious.

Second, it was not possible to estimate the parameters of any of the models in the fifth sub-sample, because there were no interest rate changes at all (no interest rate increases and no interest rate cuts) in that period.

Moreover, the results in case of the division of the sample into the sub-samples corresponding entirely with the periods of the two monetary policy rules, i.e. the first one covering the first period from August 2000 to December 2003 and the second one from January 2004 until December 2017, are not comparable due to substantially different sample sizes (less than 900 observations in the first case *versus* over 3650 observations in the second case).[2]

5.3.4. Results Based on Shorter Sample Beginning in Year 2004

We also checked the estimation results in the shorter data sample starting from the beginning of the year 2004 when, as it has been mentioned in the previous section, the new monetary policy rules (the continuous inflation target with a permissible fluctuation band) were introduced by the NBP.

In order to do it, we divided the whole period from January 2004 to December 2017 into two equal sub-samples (which, as previously, cover the high-level and low-level interest rates environments) and we re-estimated our models in these alternative two sub-periods.

Overall, these additional estimation results are very similar in terms of the value of the estimated parameters as well as their statistical significance, so they are qualitatively the same as those in the original period starting in August 2000.

[2] Due to all these reasons, we do not report those estimation results here in this report, but they are available upon request.

As an example, the estimates of the parameters for the dummy variables capturing interest rate changes upwards and downwards, which are reported in Table 2, in the first sub-period are: -0.003309 (significant at 1% level) and 0.000623 (not significant), respectively, while the estimates in the shorter sample beginning in the year 2004 are in the first sub-period: -0.003492 (also significant at 1% level) and -0.000299 (not significant either), respectively.

In the second sub-period, the estimates of the parameters for these two dummy variables in Table 2 are: -0.001490 (not significant) and -0.000410 (not significant), respectively, whereas the estimates in the shorter sample beginning in the year 2004 are in the first sub-period: -0.001486 (not significant either) and -0.000368 (not significant either).

These results mean that those estimates are not only qualitatively the same, but they are even numerically very close to each other.

The estimates from other models, both in the mean equation and in the conditional variance equation, exhibit very similar patterns, so we can conclude that our findings reported and discussed in previous sections are robust with respect to the truncation of the data sample at the beginning of the year 2004 when the new monetary policy rules were introduced by the NBP.

5.3.5. Results from Models with Additional Control Variables

Finally, we estimated more variants of models with introduced additional control variables.

For the foreign exchange market models, we used the returns of the respective foreign exchange rates against the basket of international currencies in order to control for the possible interrelationships among the foreign exchange rates.

The source of the data for the foreign exchange rates against the basket of currencies is Bloomberg.

The data about the international currencies basket from the Bloomberg database relies on the Bloomberg correlation-weighted currency indices for the major global currencies from the G-10 countries.

We determined the weights in the basket using the Bloomberg methodology to measure correlation among foreign exchange rates (instead of other traditional trade-weighted benchmarks). This new methodology designed by Bloomberg is supposed to better reflect the composition of the international currency baskets, because it not only captures the common movements between currency pairs, but it also better explains the variation within the basket and it is able to adapt on the daily basis to changing market conditions.

For the stock market models, we used international stock market indices, such as:

- MSCI World
- EuroSTOXX
- DJIA
- FTSE.

For the bonds market models, we used Barclays international bonds market index.

Therefore, in this section we estimated the following GARCH(1,1) models with the NBP interest rate announcement dummies introduced in the mean equation as well as in the conditional variance equation and, additionally, with the control variable added in the mean equation:

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \alpha_2 \cdot r_t^{control,k} + \xi_t \quad (3)$$

$$h_t^i = \beta_0 + \beta_1 \cdot \xi_{t-1}^2 + \beta_2 \cdot \sigma_{t-1}^2 + \beta_3 \cdot DUM_t \quad (4)$$

where:

$r_t^{control,k}$ – is the daily return of the specific control variable of the relevant instrument k

and as in all previous models:

DUM_t – is the dummy variable capturing the relevant interest rate changes.

Tables 35-37 present the estimation results using, again, only some representative examples for the PLN/EUR foreign exchange rate, WIG index and 1-year bond models where the basic specifications are now extended by adding the above mentioned control variables.

Table 35 shows that for the PLN/EUR foreign exchange rate the estimated parameters are very similar to the original estimates in terms of their value and the conclusions about their statistical significance in the full sample and in both sub-samples.

Likewise, the results for the WIG index and for the 1-year bond presented in Tables 36-37 show the same consistency.

Therefore, based on alternative variants of models with the addition of different control variables, we can conclude that our findings are robust with respect to these new models' specifications.

Table 35. Estimates of dummy variables INTRATE_UP and INTRATE_DOWN for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (3):

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \alpha_2 \cdot r_t^{control,k} + \xi_t$$

from the GARCH model (1) - (2) of the PLN/EUR foreign exchange rate returns with the EUR against the basket of currencies exchange rate returns as a control variable.

		Model without control variable		Model with control variable	
Equation:	**Sample:**	**Interest Rate Change Upwards**	**Interest Rate Change Downwards**	**Interest Rate Change Upwards**	**Interest Rate Change Downwards**
	PLN/EUR foreign exchange rate: Full sample				
(1)	Full sample: 1 - 4544	-0.002501 ** (0.001072)	0.000100 (0.000902)	-0.002591** (0.001091)	0.000194 (0.000952)
	PLN/EUR foreign exchange rate: 1st sub-sample				
(1)	1st sub-sample: 1 - 2272	-0.003309 *** (0.000623)	-0.000299 (0.001326)	-0.003686*** (0.001060)	0.000560 (0.001506)
	PLN/EUR foreign exchange rate: 2nd sub-sample				
(1)	2nd sub-sample: 2273 - 4544	-0.001490 (0.001686)	-0.000410 (0.001018)	-0.001117 (0.001837)	-0.000407 (0.001026)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the mean equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

Table 36. Estimates of dummy variables INTRATE_UP and INTRATE_DOWN for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (3):

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \alpha_2 \cdot r_t^{control,k} + \xi_t$$

from the GARCH model (1) - (2) of the WIG index returns with the MSCI World index returns as a control variable.

		Model without control variable		Model with control variable	
Equation:	**Sample:**	**Interest Rate Change Upwards**	**Interest Rate Change Downwards**	**Interest Rate Change Upwards**	**Interest Rate Change Downwards**
	WIG index: Full sample				
(1)	Full sample: 1 - 4544	-0.005315 ** (0.002406)	-0.001435 (0.001349)	-0.002911 ** (0.001416)	-0.000825 (0.001622)
	WIG index: 1st sub-sample				
(1)	1st sub-sample: 1 - 2272	-0.007936 *** (0.002036)	-0.001521 (0.001481)	-0.010405 *** (0.002909)	-0.001746 (0.001406)
	WIG index: 2nd sub-sample				
(1)	2nd sub-sample: 2273 - 4544	-0.004477 (0.005139)	-0.001252 (0.002311)	-0.000636 (0.002914)	0.001720 (0.001494)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the mean equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

Table 37. Estimates of dummy variables INTRATE_UP and INTRATE_DOWN for the NBP interest rates announcements on day t with the announcements dummies in the mean equation (3):

$$r_t^i = \alpha_0 + \alpha_1 \cdot DUM_t + \alpha_2 \cdot r_t^{control,k} + \xi_t$$

from the GARCH model (1) - (2) of the 1-year bond with the international bonds market index returns as a control variable.

		Model without control variable		Model with control variable	
Equation:	**Sample:**	**Interest Rate Change Upwards**	**Interest Rate Change Downwards**	**Interest Rate Change Upwards**	**Interest Rate Change Downwards**
	1-year bond: Full sample				
(1)	Full sample: 1 - 4544	0.002016 (0.001386)	-0.007398 *** (0.002471)	0.001993 (0.001549)	-0.007233 *** (0.002022)
	1-year bond: 1st sub-sample				
(1)	1st sub-sample: 1 - 2272	0.002281 (0.001781)	-0.008107 *** (0.002034)	0.002290 (0.001885)	-0.007919 *** (0.001506)
	1-year bond: 2nd sub-sample				
(1)	2nd sub-sample: 2273 - 4544	0.003353 (0.021368)	-0.003224 (0.003489)	0.003208 (0.022045)	-0.003206 (0.003452)

Notes: (1) Values of the standard errors in the brackets. (2) Number of equation in the first column indicates the mean equation of the respective GARCH model. (3) Cells highlighted grey indicate statistically significant estimates.

* - denotes significance at the 0.1 level; ** - denotes significance at the 0.05 level; *** - denotes significance at the 0.01 level

We also tested the versions of models with the NBP interest rate change announcements dummies constructed for the day after the actual announcement (i.e. for day $t+1$).

Overall, the reactions in all the investigated market segments were much weaker on day $t+1$.

6. Conclusions

The main findings and the overall conclusions from this study can be summarized as follows.

First, when the differences across the sub-samples covering high-level and low-level interest rates environments are considered, it is evident that in all market segments there is a clear dominance of more results, which are statistically significant in the first sub-period (higher interest rates environment) than in the second sub-period (lower interest rates environment).

In the mean equations, there are 21 *versus* 5 cases of the estimation results that are statistically significant in the first sub-period (higher interest rates sample) relative to the second sub-period (lower interest rates sample).

Similarly, in the conditional variance equations, there are 30 *versus* 19 cases of the estimation results that are statistically significant in the first sub-period (higher interest rates environment) relative to the second sub-period (lower interest rates environment).

Overall, across both types of equations in all our models there are over twice as many instances of the estimation results that are statistically significant in the first sub-period (higher interest rates sample) relative to the second sub-period (lower interest rates sample), i.e. 51 *versus* 24 cases.

Hence, we can conclude that there exists convincing empirical evidence showing that in the lower interest rates environment the financial market in Poland became less responsive to interest rates decisions.

This finding is consistent with the study by Wu (2016) using the US market data, which means that investors' reactions in the Polish market appear to be similar to those in the advanced markets. Since investors in these markets

tend to be informed, our results may suggest, therefore, the presence and activity of informed traders in the Polish market as well.

However, it is worthwhile to add that such result may be also partly related to the mechanics of the effect of changing level of interest rates over time (i.e. a surprise change of, for example, 50 bps is interpreted differently by the markets in the period when interest rates are high or low, e.g. when the interest rate is 14% then 50 bps change is a much smaller fraction of it than in case when the interest rate is 6%).

Second, there were also stronger reactions detected in foreign exchange rates returns and stock market returns in case of interest rates changing upwards rather than downwards, but in the bonds market this effect was opposite, i.e. there were stronger responses in case of interest rates changing downwards.

Third, in case of surprises (i.e. when interest rates were announced different than expected) the picture is ambiguous for all market segments.

Fourth, the results for the dummy variables in the conditional variance equations in all investigated models are also quite mixed. There is no clear dominance of either negative or positive estimates, which means that the NBP announcements neither calmed the markets nor increased the uncertainty among investors. The only distinct exception is stock market, where all the statistically significant estimates are always negative, which indicates strong stabilizing effects of the NBP communication in this market segment.

The conclusions from our study about the evolving nature of reactions of the financial market to the changes of interest rates in Poland may provide helpful information for policymakers regarding the impact of their policy decisions.

One of the key practical issues related to our research and the implication of our results is that the central banks' interest rate policy may not

be effective in low interest rates periods, which suggests a larger role for fiscal policy in such environments.

Our results indicate also the possibility of 'wealth effects'. From this point of view, the findings from this paper are generally consistent with the conclusions from e.g. the paper by Brzeszczyński and Kutan (2015).

On the other hand, our results based on the analysis of effects in the conditional volatility suggest that the NBP announcements may not necessarily be considered as consistent determinants of changes in the market risk (as measured by the conditional variance of returns) in the respective Polish financial market sectors covered in this research (except only for the stock market for which calming effects were found consistently in case of all the investigated stock indices).

Our findings indicate also some other avenues for future research. The extension of the analysis presented in this study can include some other aspects of financial markets' responses to central bank's announcements in high and low interest rates environments, such as e.g. investigation of responsiveness of the trading volume as the key measure of market activity.

Another possible extension can be to employ high-frequency data. New studies on advanced markets use such approach. For example, English, Van den Heuvel and Zakrajšek (2018) investigated the reaction of stock returns to the FOMC interest rate announcements in the USA applying high-frequency data. They run regressions with standard errors clustered across time to account for cross-sectional dependence in the error term and they used of a 2-hour window 15 minutes before and 105 minutes after the announcement to allow some time for price discovery to occur in the market. Their results show that unanticipated increases in interest rates have a significant impact on stock returns. As evidence on the impact of interest rate announcements on financial markets based on high-frequency data in emerging market countries is still very limited, such research would be an interesting addition to the existing literature.

Further possible extension may be the inclusion of the results from other emerging markets in Central and Eastern Europe, which have also introduced important economic reforms and experienced changes in monetary policy. As our paper is concentrated only on the Polish market, it would be worthwhile to compare the findings for Poland with those from similar models but for other markets in the broader CEE region.

Finally, most of the available studies focus predominantly on monetary policy data. However, the government decisions in terms of the fiscal policy, in particular in light of our results discussed earlier above, should also have a substantial impact on the movements of financial market instruments prices and on their volatility. Hence, the analyses of fiscal announcements in similar models as those presented in our study and the comparison of their role with that of monetary policy news would be another valuable contribution to the literature.

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