Public Information Arrival and Investor Reaction During a Period of Institutional Change: An Episode of Early Years of a Newly Independent Central Bank

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ABSTRACT:

Employing unique data derived directly from the Reuters electronic brokerage platform for currency trading, this paper investigates the reaction of investors to central bank announcements on the foreign exchange market in Poland in the years 2000-2003. Our sample period captures a time during which the National Bank of Poland (NBP) gained independence and it was transforming institutionally and switching to a new monetary policy regime; namely inflation targeting. Evidence indicates that central bank communication helped reduce foreign exchange market uncertainty, measured by the conditional variance of foreign exchange returns, and increased trading volume. The findings suggest that in newly emerging economies with major institutional changes, investors may react significantly to central bank communication, and central banks can hence play an important role in market development during an institutional change. Our results also have broader implications for the applicability of micro-structure models in newly emerging economies.

Keywords: institutional change, foreign exchange market, central bank, macroeconomic announcements, investor reaction, trading volume and volatility

JEL classification: E5, F3, G1, O2, P3

1. Introduction

Starting from the early 1990s, many Central and Eastern European (CEE) countries have implemented major economic and financial reforms, including the establishment of an independent central bank, resulting in the emergence of new financial instruments and significant financial market development. Since 2004, most of these countries have now joined the European Union (EU), and some of them are also included in the Eurozone. However, despite significant reforms having been implemented, only a few empirical studies have examined the developments in the financial markets of the new EU countries. In this paper, we focus on the Polish foreign exchange market returns and trading volume and provide evidence on how foreign exchange market investors react to public information arrival, measured by central bank announcements.

We employ both a unique data set, which includes the foreign exchange market returns and volume of trade, and a sample period (2000-2003) that allows us to capture the reaction of investors to communications of a freshly instituted Monetary Policy Council (MPC) and a transforming new independent central bank. During our sample period, the National Bank of Poland (NBP) had emphasized transparency as a key component of their monetary policymaking. Hence, our findings shed some light on the question of how a newly established institution implementing significant policy changes (namely, inflation targeting regime) along with a new institutional structure (i.e. a new independent central bank and the introduction of the MPC) in an emerging market economy affects investor behavior. In this paper, we are interested in both the wealth and uncertainty (i.e. risk) effects of central bank announcements during a period of major institutional change. As the independent central banks in the CEE countries are relatively new, one of their key objectives is to provide a transparent central communication mechanism intended to reduce uncertainty in financial

markets. Our paper is similar in spirit to the work by Gómez, Melvin and Nardari (2006), who investigated the introduction of the new European Central Bank (ECB) and how ECB actions had affected investor reaction and hence the determination of the euro exchange rate.

Studying the Polish foreign exchange market is both interesting and important for several other reasons. First, there is scant evidence on the impact of public information arrival in newly emerging European financial markets. It is well known that public information arrival, typically measured by the publicly released economic and financial data, is a building block of many theoretical models of asset price determination.[1] Although the empirical evidence on linking public information to asset market behavior is still accumulating, the main focus has been mostly on industrial countries.[2] Previous studies that have tested the importance of public information in explaining variation in asset returns in advanced markets typically indicate mixed evidence.[3] Thus, our paper providing further evidence on the importance of public information arrival in an emerging EU market, contained in central bank announcements in the Polish foreign exchange market, contributes to this line of literature. To the best of our knowledge, there is hardly any evidence on the significance of public information arrival in Poland.[4]

Second, the establishment of independent central banks in CEE countries is relatively new, and there is therefore not much accumulated evidence regarding whether central bank announcements in these economies can create wealth effects *via* movements in foreign exchange rates and if they can reduce market uncertainty.

[1] For example, the mixture of distributions model (MODM) and the recent microstructure theories rely on public information arrival to explain movements in asset returns. MODM models are associated with Clark (1973) and Tauchen and Pitts (1983), while microstructure theories are reviewed in O'Hara (1995) and Lyons (2001).
[2] Melvin and Yin (2006) and Edmonds and Kutan (2002) provide a review of recent work.
[3] See, for example, Cutler, Poterba and Summers (1989), Berry and Howe (1994), Mitchell and Mulherin (1994) and, Andersen, Bollerslev and Cai (2000).
[4] To the best of our knowledge, there are two other related studies on Poland (see Serwa (2006) and Rozkrut et al. (2007)), however our paper is quite different from them. We explain the differences between our and their contribution in the next sections.

Third, understanding the empirical link between monetary policy announcements, including those of money supply and exchange rate changes, helps better understand how monetary transmission mechanism works in emerging economies under significant institutional changes. Although the Polish market is relatively small, it is very dynamic and has grown rapidly. It is by far the largest financial market and the biggest economy in the CEE region. It is expected that such a transmission channel, if it exists, will play a much more important role in the near future as the National Bank of Poland becomes much stronger institutionally, and as Poland becomes an important financial market in the region and prepares for Eurozone membership. If a significant empirical link exists between monetary policy announcements and foreign exchange market activity, then exchange rates could play a more important role in monetary policy decisions or policy rules. Hence, this paper also contributes to the literature on the role of asset prices in the monetary transmission mechanism.[5]

Fourth, investor reaction in emerging markets can be different from that in other developed markets due to different historical, cultural, and institutional factors that these countries have. In particular, investors may or may not react to "news" in a similar fashion as those in other developed economies do.[6] Our results also have implications for short-run investors, such as speculators, as we provide daily evidence regarding whether central bank communication creates significant changes in market returns affecting wealth and trading volume.

Fifth, previous studies (especially those using the data from the CEE countries) have focused mainly on stock markets, with hardly any evidence from the foreign exchange

[5] For a review of these issues, see Modigliani (1971), Mishkin (1977 and 2007), Kamin, Turner and Van't dack (1998), Gilchrist and Leahy (2002), and Ehrmann and Fratzscher (2004).

[6] Reactions of investors in emerging financial markets to news may be different than those in industrial countries due to several factors including weak monetary authorities, limited investor confidence, inefficient financial markets and differences in their exchange rate regimes as well as the degree of integration of their markets with the global financial system (for further discussion and empirical evidence, see Serwa (2006), Wongswan (2009) and Hausman and Wongswan (2011)).

market.[7] Therefore, we also fill the gap in the literature by providing new evidence on the impact of central bank announcements on foreign exchange market returns and volatility in Poland.[8]

The work that is closest to ours is the undertaking by Serwa (2006) who provides evidence on the short-run reactions of the emerging financial market in Poland to domestic central bank monetary policy announcements, measured by changes in the official interest rate. Findings presented by Serwa (2006) show that only the short-term interest rates respond significantly to the official interest changes but not the long-term interest rates, stock indices or foreign exchange rates. Serwa (2006) concluded that the unexpected monetary policy changes have stronger influence on the money market than the nominal changes in the official interest rate on the days of the monetary policy announcements. Our paper is different from that work. While Serwa (2006) focuses on the official rate changes, we actually analyze a battery of announcements made by the Polish central bank, including those on monetary aggregates, and we do not cover official rate announcements. Most importantly, we employ a unique, proprietary, data set of foreign exchange market volume of trade that has not been used in the literature yet.

In another paper related paper to ours, Rozkrut et al. (2007) investigated the impact of statements of the key policy makers 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: the Czech Republic, Hungary and Poland. They found that the verbal comments of policy makers in the Czech Republic, Hungary, and Poland influenced behavior of the currency market but that this effect differed

[7] See, among others, Ganapolsky and Schmuckler (2001), Kaminsky and Schmukler (2002), Korczak and Bohl (2005), Nikkinen, Omran, Sahlström and Äijö (2006), Robitaille and Roush (2006), Wongswan (2009), Hanousek, Kočenda and Kutan (2009). There is only a limited number of papers concerning other market segments (see e.g. Andritzky, Bannister and Tamirisa (2007), Poghosyan, Kočenda and Zemčik (2008) or Loiseau–Aslanidi (2011)).

[8] Poland is the largest currency market in the CEE region. According to the Bank for International Settlements (BIS) triennial reports, the snapshot surveys conducted in 2001, 2004, 2007, 2010 and 2013 show that it was roughly twice as large in size as the second biggest markets in the Czech Republic and in Hungary (see: Triennial Central Bank Survey (2010) and Triennial Central Bank Survey (2013)).

among the countries. Our paper also differs from Rozkrut et al. (2007). They examined verbal statements, while we focus on MPC communications. Again, we use a proprietary data set on the PLN/USD volume of trade, which has not been exploited in the existing literature before. Overall, there are a limited number of studies on emerging markets, especially on emerging EU markets, and they focus mainly only on stock markets with only some evidence documenting the responses of other instruments, such as bonds, interest rates and currencies. Most of these studies focus on financial market returns and do not examine findings for the trading volume. Our paper provides results for the foreign exchange market using not only the exchange rate returns but also the foreign exchange (FX) volume of trade.

This paper is organized as follows: Section 2 discusses the policy of the National Bank of Poland, the Monetary Policy Council decisions, and describes the MPC communication policies during our sample period (2000-2003) capturing the early years of the NBP. Section 3 explains the empirical methodology used, and sections 4, 5, 6 and 7 present and discuss the dataset, the empirical results, robustness checks and investment strategy, respectively. The last section concludes the paper and considers the policy implications of the findings.

2. Central Bank Policy and Monetary Policy Council Decisions (1999-2003)

The National Bank of Poland (NBP) became independent in the early 1990s as a result of political changes and economic reforms undertaken by the new Polish democratic governments, which came to power when the centrally planned economy collapsed in 1989. The Monetary Policy Council (MPC) was established in February 1998. The monetary policy of the NBP is in practice executed by the MPC, which consists of the president of the central bank, who chairs the Council, plus nine members appointed by the President, the Senate and the Sejm (Parliament).

In September 1998, the MPC announced its *"Medium-Term Strategy of Monetary Policy (1999-2003)"* document, which introduced the Direct Inflation Target (DIT) and determined the medium-term monetary policy target, i.e. a consumer price growth rate reduction to below 4% in 2003.[9] Since 1999, a Direct Inflation Target strategy has been utilized in the implementation of the NBP monetary policy.[10] Within the framework of this strategy, the Monetary Policy Council of the NBP defines the inflation target and then adjusts the NBP basic interest rates in order to maximize the probability of achieving its target. The NBP stated also that under the DIT system, the efficient co-ordination of monetary, income and fiscal policies is particularly critical. A possible inconsistency between these policies could undermine the credibility of the planned pace of disinflation. Using fiscal policy instruments and administrative price and wage adjustments, it was believed that the government can exert a significant impact on inflation. Therefore, a consistency between the fiscal stance and the inflationary target used by NBP would be the main criterion applied by the Council in the formulation of the opinion on the national budget. In order to foster the credibility of disinflation policy, the Council would make efforts to ensure greater consistency between the information policies of the government and the central bank.

The NBP also believed that the increasing sensitivity of the Polish economy to the developments in international financial markets required its stronger resilience, which, in turn, would influence the effectiveness of monetary policy. It stated that as a result it would be necessary to maintain sufficiently large foreign exchange reserves. These reserves

[9] The MPC believed that the adoption of the DIT strategy was the most beneficial as other strategies (i.e., monetary aggregate or exchange rate targeting) did not guarantee a lasting reduction of the inflation rate (in the case of the monetary aggregates control) or exposed the economy to the risk of serious distortions on the financial market, with all the concomitant adverse consequences for the real economic sector (with maintained exchange rate targeting).

[10] According to the Article 227, Paragraph 1, of the Constitution of the Republic of Poland *"the National Bank of Poland shall be responsible for the value of Polish currency"*. The Act on the National Bank of Poland of 29 August 1997 states in Article 3 that *"the basic objective of NBP activity shall be to maintain price stability, and it shall at the same time act in support of Government economic policies, insofar as this does not constrain pursuit of the basic objective of the NBP"*.

ought to stabilize the Polish zloty (PLN) exchange rate in the event of significant disturbances in the foreign exchange market, and to facilitate the rapidly expanding convertibility of the zloty and the increased debt repayments anticipated in the near future (*Medium-Term Strategy of Monetary Policy (1999-2003)*).

Since the year 2000, the zloty exchange rate has been a floating exchange rate that is not subject to any restrictions. The central bank does not aim to set predetermined zloty exchange rates against other currencies. Nevertheless, the NBP reserves the right to intervene if it deems this necessary in order to achieve the inflation target. It clearly states that foreign exchange interventions are a monetary policy instrument that may be used by the central bank. Exchange rate fluctuations exert a considerable impact on inflation, thus circumstances may arise in which the MPC decides it is necessary to intervene in the foreign exchange market in order to stabilize inflation. Should Poland join ERM II, interventions in the foreign exchange market may also be used to stabilize the zloty exchange rate for the exchange rate stability criterion to be met (*Monetary Policy Guidelines for 2009*).[11]

Overall, the NBP believes that continued support for monetary policy underpinned by vigorous publicity is vital to reduce uncertainty and develop an understanding of the decisions made by the central bank among market participants. Such publicity is also believed to enhance the transparency and credibility of monetary policy. The NBP aims at conducting an open attitude in its communication policy and believes that market

[11] After the year 2003, which is the period beyond our study, the NBP changed its policy due to low inflation. After a long period of lowering the inflation rate, its monetary policy after 2003 was oriented towards its stabilization at a low level. Equally important, the Council believed that Poland's prospective membership in the EU beginning in 2004 necessitated the stabilization of inflation at a level consistent with an economic policy strategy that assumed Poland's joining the Eurozone at the earliest date possible (*Monetary Policy Strategy Beyond 2003*). Since the beginning of 2004, the NBP has pursued a continuous inflation target at the level of 2.5% with a permissible fluctuation band of +/- 1 percentage point. The MPC pursues this strategy under a floating exchange rate regime. The NBP maintains interest rates at a level consistent with the adopted inflation target by aiming to influence the level of nominal short-term interest rates on the money market. The set of monetary policy instruments used by the NBP enables it to determine interest rates on the market. These instruments include open market operations, reserve requirements and credit-deposit operations (*Monetary Policy Guidelines for 2009*). Currently, the basic objective of the monetary policy (conducted from 2009) is to maintain inflation at the level of 2.5% in the medium term. At the same time, monetary policy will continue to be conducted in such a way so as to support sustainable economic growth.

participants have relatively little difficulty in assessing its decisions in terms of the achievement of the monetary objectives set by the bank. Furthermore, the NBP believes that active public relations policy contributes to increased responsibility and accountability of the central bank to market players for the monetary policy it conducts. Key instruments employed in public communication include quarterly inflation reports published by the bank, information from the Council's meetings, other materials published on the NBP website, press conferences, public speeches as well as participation in seminars and scientific conferences (*Monetary Policy Strategy Beyond 2003*).

3. Methodological Issues

In this section, we first discuss modeling of the foreign exchange returns followed by the trading volume. Because strong ARCH effects were detected in exchange rate returns and trading volume models, we utilize ARCH methodology in modeling both variables.

3.1. Foreign Exchange Returns and Volatility

We propose to estimate the following GARCH(1,1) model of the PLN/USD exchange rate returns ($r_t^{PLN/USD}$) with surprise announcement dummies for each variable in the mean and the conditional variance equations in order to test whether the unexpected central bank announcements affect the mean and the variance of the foreign exchange rate:

$$r_t^{PLN/USD} = \alpha_0 + \alpha_1 \cdot \Delta Volume_{t-1} + \alpha_2 \cdot r_t^{EUR/USD} + \\ + \alpha_3 \cdot INTDIFF_t + \sum_{s=4}^{7} \alpha_s \cdot DUM_{s,t} + \xi_t \qquad (1)$$

$$h_t^{PLN/USD} = \beta_0 + \beta_1 \cdot \xi_{t-1}^2 + \beta_2 \cdot h_{t-1} + \beta_3 \cdot \Delta Volume_{t-1} + \sum_{p=4}^{7} \beta_p \cdot DUM_{p,t} \qquad (2)$$

where:

$\Delta Volume_t$ - is the percentage change of trading volume,

$r_t^{EUR/USD}$ - is the return of the EUR/USD exchange rate,

$INTDIFF_t$ - is the interest rates differential between the USA and Poland,

DUM_s and DUM_p - are the dummy variables with different strengths (strongly positive, positive, negative and strongly negative) for $s = 4,..,7$ and $p = 4,..,7$, respectively, for the NBP announcements: MS, RM, BOP, AL,

$h_t^{PLN/USD}$ - is the conditional variance of the returns (and $h_{t-1}^{PLN/USD}$ measures the persistency in the variance equation),

ξ_t - is the surprise component of the variance equation.

During our sample period the euro was introduced, and this new currency could have affected the foreign exchange market activity in Poland. In addition, interest rate changes could have influenced the movements and the volatility in the foreign exchange returns as well.[12] Therefore, the variables (i) interest rate differentials between the USA and Poland[13] and (ii) return of the EUR/USD exchange rate (US dollar - euro) are included in the above model in the mean equation (1) as control variables.

The lagged volume variable $\Delta Volume_{t-1}$ is introduced in the mean equation (1) under the assumption that price and quantity in the foreign exchange market are determined jointly (so we do not assume independent random walks). In the conditional variance equation (2) the lagged $\Delta Volume_{t-1}$ is used to avoid any possible simultaneity bias, which could appear if it was omitted from the model.

[12] For example, Gabrisch and Orlowski (2010) report strong linkages between Polish and Eurozone bond yields, which would be reflected in the EUR/USD foreign exchange rate returns.
[13] The US interest rate used is the FOMC Fed Funds Rate while the Polish interest rate is Stopa Referencyjna of the NBP.

Figures 1, 2, 3 and 4 present the PLN/USD and EUR/USD exchange rate returns, levels of the PLN/USD and EUR/USD exchange rates and the US and Polish interest rates with their differentials, respectively.

[Figures 1, 2, 3 and 4 around here]

3.2. Foreign Exchange Volume of Trade and Volatility

Similarly, we employ a GARCH(1,1) model to estimate the impact of unexpected central bank announcements on the PLN/USD volume of trade ($\Delta Volume_t$) with announcement dummy variables in the mean and in the conditional variance equations:

$$\Delta Volume_t = \alpha_0 + \alpha_1 \cdot r_{t-1}^{PLN/USD} + \alpha_2 \cdot \sqrt{h_t^{PLN/USD}} + \sum_{s=3}^{6} \alpha_s \cdot DUM_{s,t} + \xi_t \qquad (3)$$

$$h_t^{volume} = \beta_0 + \beta_1 \cdot \xi_{t-1}^2 + \beta_2 \cdot h_{t-1} + \beta_3 \cdot r_{t-1}^{PLN/USD} + \sum_{p=4}^{7} \beta_p \cdot DUM_{p,t} \ . \qquad (4)$$

where h_t^{volume} is the conditional variance of the trading volume (and h_{t-1}^{volume} measures the persistency in the variance equation), and , as above, DUM_s and DUM_p are dummy variables with different strengths (strongly positive, positive, negative and strongly negative) for $s = 4,..,7$ and $p = 4,..,7$, respectively, for the announcements: MS, RM, BOP, AL .

The variable $h_t^{PLN/USD}$ is the variance h_t extracted from the PLN/USD exchange rate returns model (1) - (2), but in its cleanest and simplest form, i.e. without the NBP announcements dummies or other variables in (1) and (2), i.e. from a simple GARCH(1,1) model:

$$r_t^{PLN/USD} = \alpha_0 + \xi_t \tag{5}$$

$$h_t^{PLN/USD} = \beta_0 + \beta_1 \cdot \xi_{t-1}^2 + \beta_2 \cdot h_{t-1}. \tag{6}$$

A GARCH type model of the form (1) - (2) or (5) - (6) provides useful information about the conditional variance of exchange rate returns $h_t^{PLN/USD}$ (captured by equations (2) and (6)), which may be further exploited to investigate the impact of the PLN/USD exchange rate returns variance on the trading activity. We check this effect for the volume of trade models using the model specification expressed by equations (3) – (4). The estimates of the parameter α_2 associated with the variable $\sqrt{h_t^{PLN/USD}}$ in equation (3) allow us to ascertain whether the exchange rate volatility has an effect on the market activity as measured by changes in the PLN/USD volume of trade.

Similarly to the foreign exchange models discussed in the previous section, the lagged foreign exchange return variable $r_{t-1}^{PLN/USD}$ is introduced in the mean equation (3) following the same assumption that price and quantity in the foreign exchange market are determined jointly (so we do not assume independent random walks). In the conditional variance equation (4) the lagged $r_{t-1}^{PLN/USD}$ is used to avoid any possible simultaneity bias.

As previously, the variable $\Delta Volume_t$ is defined as a daily percentage change of the PLN/USD foreign exchange volume of trade. The original trading volume data were extracted directly from Reuters electronic brokerage platform for currency trading.

Figure 5 plots the volume of trade of the PLN/USD foreign exchange rate.

[Figure 5 around here]

4. Empirical Results

In this section, we describe the dataset, the sample period, and present empirical results. We first present estimates for the mean equations followed by those of the conditional variance equations. We initially focus the discussion on money supply announcements followed by a discussion of findings for the remaining three announcements types.

4.1. Data and Descriptive Statistics

In this paper, we utilize the information about the announcements of the Council's meetings during 1999-2003 obtained from the NBP. The Council typically meets twice a month and makes announcements in a number of areas, such as: Money Supply (MS) and Reserve Money (RM), Balance of Payments (BOP), Official Reserves ($OFRES$), Liquid Assets and Liabilities in Foreign Currencies (AL), Foreign Debt ($FDEBT$) and International Investment Position (IIP) (See Table 1a). These announcements are data about the publication of actual new monetary figures (i.e. they are not targets or forecasts). Our analysis relies on the information, obtained directly from the Polish central bank, about the exact time of the day when the announcements were made.[14]

[Table 1a around here]

The announcements for Official Reserves and the Reserve Money were always made on the same day, so we used only one of these (RM) for both those types of news. The IIP dummy had only one announcement in the analyzed period of time (and it was the last observation in the sample), so we removed it from our analysis. The publication of data

[14] Prior to March 1st 2006 all regular announcements had always been made at 4:00 PM (and after that date at 2:00 PM).

about Foreign Debt (*FDEBT*) began in the second quarter of 2002, and contained only 5 observations in our whole sample period, so we did not use it in our analysis either. Regular announcements for the quarterly Balance of Payments started only after the end of our sample, so we did not consider this variable as our dummy, but we could use monthly Balance of Payments (*BOP*), which had been released on a regular basis every month. All other data were based on very regular, monthly frequency, announcements in the investigated data sample. In total, our sample covers 150 individual announcements made by the Polish central bank NBP. Table 1a provides a detailed summary of all the types of announcements used in this study.

It is well known that investors react to only new or surprise information. However, since no information about actual expectations regarding the NBP announcements figures for the period of our analysis is available (from, for example, surveys), we could not use any such data in this study to define the unexpected announcements.[15] Hence, we constructed surprise announcements in this paper by determining the deviation of the actual announcements, in the form of the new figures released by the NBP, from their respective moving averages (3-months moving average, based on the data from periods t-2, t-1 and t, for all monthly announcements, i.e. for *MS*, *RM*, *BOP* and *AL*). Using this data, in the next step we calculated the standard deviation (SD) of the announcements figures for each variable and we divided these deviations by their SD, i.e. obtaining the proportions in their SDs. This allowed us to create a ranking of unexpected announcements from the highest positive to the highest negative proportion, and using their span we divided this data into five baskets. Through this approach we obtained five groups of unexpected announcements: strongly positive, positive, neutral, negative, and strongly negative.

Figure 6 illustrates the unexpected announcements as a proportion of the deviation from their moving average in their standard deviation. For example, the first reserve money

[15] Reuters has been conducting surveys of financial market participants in Poland on expectations of some macroeconomic variables but unfortunately they did not cover the expectations of the NBP announcements, which we use in this study.

(RM) announcement in Figure 6 in August 2000 was 53,624.85 million PLN and the moving average then was 51,039.47 million PLN, so the deviation is +2,585.38 million PLN. The standard deviation of RM announcements was 6,128.25 million PLN, hence the proportion of this deviation (+2,585.38 million PLN) was 0.42 or 42% (i.e. 2,585.38 / 6,128.25 = 0.42).

[Figure 6 around here]

This procedure allowed us to create 5 groups of unexpected announcements: strongly positive, positive, neutral, negative, and strongly negative. Consequently, we defined four (0, 1) dummies for: strongly positive, positive, negative and strongly negative unexpected announcements for all our NBP variables (MS, RM, BOP and AL), omitting the neutral case when the announced figures were in the middle quintile, so they did not differ from the moving average. We assume that investors' interpretation of the deviations depends on how they perceive the changes in the new announcements. If the changes are viewed as "transitory" then they would expect that the central bank would revert back to the trend. If investors perceive the surprise changes as "permanent" then the anticipation is that there would be no return to the trend. Out of all 150 NBP announcements in our study, 35 were of the greatest strength (strongly positive and strongly negative), 50 of the medium strength (positive and negative) and 65 were in the neutral band. Table 1b presents the exact numbers of the NBP announcements with different strengths, based on their division into baskets according to the magnitude of their deviations from respective moving averages. In addition, Table A1 in the Appendix shows the exact ranking and precise division of unexpected announcements into all 5 baskets.

[Table 1b around here]

In this paper we also employ a unique data set. The data about the PLN/USD (zloty-US dollar) exchange rates and the PLN/USD volume of trade were obtained directly from Reuters and were drawn from this data original source: i.e. from Reuters electronic brokerage platform for currency trading. The uniqueness of this dataset is related to the fact that the FX market volume data is not publicly available because it is proprietary information of the companies that own and operate the currency trading platforms. Hence, it normally cannot be easily accessed and used for research. The information about the dates when the news was released by the NBP was obtained directly from the National Bank of Poland.

The data for exchange rates and volume of trade has a daily frequency. The volume data was available in the Reuters database in the form of both the dollar value and as the number of trades. Following the study of Brzeszczyński and Melvin (2006), we have chosen the number of trades as an indicator of trading activity because it does not include the effect of exchange rate changes, which might result in a misleading characterization of trading intensity. Therefore, the number of trades is a better metric of market activity and we used the same definition as in Brzeszczyński and Melvin (2006) who applied similar data, but for the EUR/USD volume of trade.

The Reuters database covers the period from 1 January 1999 to 7 October 2003.[16] Our analysis concerns, however, the time period from August 2000, which was the first month when regular announcements by the Polish central bank started[17], until the end of September 2003 (last full calendar month in the Reuters volume database), and contains a total of 792 daily observations (after filtering out low volume days). Again, this time period corresponds to a major institutional change, as the Polish central bank was in the initial stages of its development as an institution in a market economy setting, and had just begun

[16] This is the time frame that the data provider released and no other, more recent, information was made available at this time. Unfortunately, this is very typical in microstructure finance and empirical research.

[17] Before that time, the central bank had a completely different method of information dissemination. There was no regular schedule, which would be published in advance. The NBP press office sent announcements only to selected news agencies (by fax). This meant that not all market participants received the information at the same time (depending on which news agency service they subscribed to and what the delay of news publication in those agencies was). Additionally, it is not possible to identify the exact time of those announcements. That is why we focus on this time frame in this paper.

the initial implementation of an inflation targeting regime. As a result, our findings allow us to capture the reaction of market participants to central bank communication by a newly institutionalized central bank and MPC, which was, at the same time, switching to a new monetary policy regime. This therefore provides a unique laboratory to understand the behavior of traders during such an extraordinary set of events.

Another important benefit of using this dataset is that the Reuters electronic brokerage platform has the highest market share in the global currency market trading among all other similar dealing systems. According to the information we received from the officials at the National Bank of Poland and Reuters in Warsaw who had access to data in the early 2000s, in the period of time analyzed in this paper Reuters served over 90% of transactions in the Polish zloty in the market in Poland and about 50% in the zloty off-shore market.

The raw data has been adjusted by removing the low volume days, such as holidays and Sundays (which contained accidental outliers).[18] The procedure for removing low volume days is similar to the one applied in Brzeszczyński and Melvin (2006) in the study about the EUR/USD volume of trade.

[Table 2 around here]

Table 2 provides descriptive statistics for both foreign exchange rate returns and trading volume. Returns are calculated as holding period returns using the first opening price and last closing price on every day. With regard to volume we used the percentage change of PLN/USD number of trades on every day. During our sample period, the daily foreign exchange rate returns ranged from -2.6% (minimum) to 4.3% (maximum), while the

[18] The holidays were: Polish national holiday Independence Day (November 11), religious holidays (Easter on various dates, usually the beginning of April; Christmas on December 25-26; August and June holidays, the latter two also on differing dates), and other holidays (such as, e.g., May 1).

trading volume changes were between -74% (minimum) and 268% (maximum). As expected, the trading volume is much more volatile than the exchange rate returns.

4.2. Results for the Money Supply (MS) Announcements

We start with the discussion of an impact of the first type of the NBP announcement, i.e. the release of the money supply (MS) figures, which we focus on first as an example of the monetary policy variable that has been investigated in the literature for the longest time (see: Neely and Dey (2010)). Subsequently, in the next section, we discuss the results for the remaining three announcement dummies (RM, BOP and AL).

Early theoretical predictions about the reaction of the foreign exchange rates in response to new money supply data clearly indicate that when the announced money supply figures are greater than expected, the nominal interest rates should rise and the related flows of capital should lead to a depreciation of the local currency (through the Fisher effect). Theoretical models describing this mechanism were presented in the 1970s by Frenkel (1976), Dornbusch (1976) and Frankel (1979), among others. Therefore, the theory suggests that positive and strongly positive NBP announcements should result in a depreciation of the Polish zloty and negative and strongly negative ones should lead to its appreciation.

However, Engel and Frankel (1984) found, using US market data, that when the US money supply figures announced were greater than had been expected, the US dollar appreciated. They explain this phenomenon by proposing a hypothesis that the market perceives the change in the money stock as only a *"transitory fluctuation"* which the Federal Reserve will reverse in the future. Engel and Frankel (1984) argue that positive money supply shocks raise interest rates by creating expectations that the Fed would reverse those positive shocks in the future through raising interest rates, and that this is why this

mechanism causes such a direction of the foreign exchange rate reactions. A similar explanation was proposed by Cornell (1982).

Regarding the impact of announcements on volatility of the foreign exchange market, the theoretical predictions as well as evidence in the available literature tend to indicate that, as Neely (2011) notes, the most common theme is that the arrival of information typically increases volatility. However, this issue is more complex in practice, and the reaction of the foreign exchange market may depend on a number of factors: the type of news, the type of institution releasing the information, as well as the length of the time horizon during which the effect on volatility is measured. The prevailing conclusion in the literature is that trading activity and volatility typically increase in ultra-short periods, i.e. for about an hour after an announcement (see: Neely (2011)), while in this study we measure the effects of the NBP communication in periods longer than one day. Moreover, the findings in this part of the literature that deals specifically with the announcements made by the central banks indicate that their actions may, in fact, reduce volatility by resolving uncertainty associated with the release of news or when their communication anchors longer-term expectations of central banks' policies (see e.g. Sager and Taylor (2004), Melvin et al. (2010), Conrad and Lamla (2010) and Hayo and Neuenkirch (2012)).

In the remaining part of this section, we check, first, if the unexpected news from the NBP had a significant effect on the foreign-exchange market. We do this by focusing on the analysis of dummies' estimates in the mean equation and, in the second step, we investigate the effects in the variance equation.

Tables 3a and 3b report the estimates from the GARCH model of exchange rate returns where the dummy variables are included in the mean and in the variance equations (i.e. in equations (1) and (2)).[19, 20]

[19] All estimations for this and all subsequent models are based on the normal distribution assumption about the error term and heteroscedasticity-consistent errors (i.e. the Bollerslev-Wooldridge hetoroscedasticity-consistent variance) are used. However, we deal with other distributional assumptions in the section on

Because all announcements were always made in the late afternoon at 4:00 PM in our sample period (see footnote 14), all variants of the model were estimated with the NBP announcement dummies for day t (i.e. the announcement day) and the next day $t+1$ to capture the possibility that some investors may have received the announcement the next day (or they may have reacted to it after a delay). For space considerations we only report the estimates of the dummy variables and other key coefficients in this and all other tables. The detailed results are available from the authors.

The first panels in Tables 3a and 3b present the estimates for the surprise announcement dummy variables for the model of the PLN/USD exchange rate returns (i.e. from equation (1)). All variants of the model were estimated with the MS dummy (and other dummies discussed in the next section) for days t and $t+1$.

[Tables 3a and 3b around here]

The results on the announcement date show that a strongly negative MS announcement depreciated the domestic currency by about 0.20% against the US dollar. However, on the next day, a strongly negative MS announcement caused the appreciation of the PLN/USD exchange rate by -1.02%. The interest rate differential variable was not statistically significant either on day t or day $t+1$, but there is strong evidence of significant EUR/USD exchange rate returns on both days (at the 1% level).

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robustness (see section 5 for more details). In all models, in cases when heteroscedasticity was strong and ARCH effects were persistent we estimated the GARCH models with a higher order of lags.

[20] The models (1)-(2) and (3)-(4) have a simultaneous nature, so we recognize the fact that the estimation results may be subject to a potential simultaneity bias and, therefore, that a correction of standard errors may be required. However, there is no need to make any further corrections of standard errors in our models other than the correction mentioned in the previous footnote by applying heteroscedasticity-consistent errors based on the Bollerslev-Wooldridge heteroscedasticity-consistent variance, which is sufficiently conservative for hypothesis testing in this case. We are grateful to the Anonymous Referee for drawing our attention to this problem which helped us address it in this study. We would like to thank also Christian Hansen, Jeffrey Wooldridge, Michael Melvin and Mark Schaffer for very helpful discussion regarding this and other related econometric issues.

The reaction of the PLN/USD exchange rate on days t and $t+1$ seems to confirm both effects predicted by the theory and evidenced by other available empirical findings discussed above. On day t, the positive sign of the strongly negative MS dummy indicates that the Polish zloty initially depreciated in response to the strongly negative money supply announcements, so the foreign exchange rate reaction was in line with the classical theoretical predictions from the models of Frenkel (1976), Dornbusch (1976) and Frankel (1979) etc. However, this effect was reversed (with much greater strength) on day $t+1$ and the foreign exchange rate reaction became consistent with the mechanism described by Engel and Frankel (1984) and with their hypothesis about the perception of the money supply data announced at a level different from the one expected by market participants as a *"transitory fluctuation"*.

Hence, it seems that on day t the investors reacted to the NBP news about the money supply, which was announced at a substantially lower level than anticipated (the MS dummy which is significant on day t, as well as on day $t+1$, is of the greatest strength, i.e. strongly negative), as predicted by the classical economic theory. However, they revised their expectations consistently with the Engel-Frankel effect subsequently on the next day $t+1$ (perhaps interpreting the NBP news as the indication of a signal for possible change of the NBP monetary policy in the future).

We also report the results of some diagnostic tests in Tables 3a and 3b (and in the consequent tables) for serial correlation and remaining ARCH effects in estimated models. The results in Tables 3a and 3b (and others) indicate that the models do not suffer from serial correlation and capture well all ARCH effects present in the data.

Next we focus on the impact of the money supply announcements on market activity measured by the changes in trading volume.

The first panels in Tables 4a and 4b present the estimates of the unexpected announcement variables for the model of the PLN/USD volume of trade percentage

changes ($\Delta Volume_t$), i.e. the estimates from equation (3). On the announcement date (day t), a statistically significant result was found for the strongly positive money supply MS dummy. The surprise strongly positive money supply news increased trading volume by about 18% This means a substantial reaction in comparison with the average (mean) daily percentage change of the trading volume of 10.54% (as reported in Table 2). A statistically significant and positive effect for the money supply dummy was also detected for the strongly negative MS dummy on day $t+1$.

[Tables 4a and 4b around here]

The GARCH-in-mean term is significant at the 5% and 10% levels, and negative in the models with the MS dummies on both days t and day $t+1$, respectively, showing further evidence of calming effects of the exchange rate volatility on the market activity.

We now turn our attention to analysis of results from the variance equations of the foreign exchange returns and trading volume models. Analysis of estimates from the models with exchange rate returns and trading volume as the dependent variables allows us to further investigate the impact of NBP announcements on foreign exchange market activity.

The second panels in Tables 3a and 3b show the estimates of the GARCH model for exchange rate returns where the dummy variables are included in the conditional variance function (i.e. equation (2)). On the announcement date (day t), the estimates for all four MS dummies with different strengths (strongly positive, positive, negative and strongly negative) are statistically significant (all at the 1% significance level) and all have negative signs. The estimated parameters range between -0.289206 and -0.519109. This means that the release of new money supply data by the NBP had a significant calming impact on the conditional volatility (i.e. risk) of foreign exchange returns. On the following day after the

NBP communication (day $t+1$), only one dummy for the MS strongly negative announcement is significant but the sign of its estimate is consistently negative.

The second panels in Tables 4a and 4b report the estimates of the GARCH model for the volume of trade percentage changes where the dummy variables are included in the conditional variance function (i.e. equation (4)). On the day of the announcement, the MS dummy has a statistically significant effect on the volatility for strongly positive and positive surprises. In both these cases the estimates are negative -1633.327 and -1009.098 for strongly positive and positive MS dummies, respectively, and they are both significant at the 1% level. Similarly to the results from Tables 3a and 3b regarding the impact of the money supply announcements on foreign exchange rate volatility, this finding again suggests the existence of calming effects. On the subsequent day, the same negative effect is also present in the case of the strongly negative surprise. The estimate equals -1529.441 and it is significant at the 1% level.

The results in Tables 4a and 4b also show the significance of the GARCH-in-mean term. The estimate of the GARCH-in-mean parameter for both days t and $t+1$ is negative and statistically significant (at 5% and 1% level, respectively). For day t, a 1% increase in the *standard deviation* of the foreign exchange returns brings a -19.71% decline in the trading volume and a -18.35% decline on day $t+1$. An increase in the standard deviation of the foreign exchange rate returns means a higher risk and this effect is associated with a decline in the trading volume. The estimated reduction of volume is substantial relative to the average (mean) daily percentage changes of the volume of trade (reported at the 10.54% level in Table 2).

Overall, the results in Tables 3a-3b and Tables 4a-4b show that the conditional volatility of foreign exchange returns and trading volume declines when the NBP announcements about new money supply figures were revealed, which may be explained by the fact that in these situations investors face less uncertainty or lower risk. This

evidence is consistent with the findings from the models of the volume of trade that market activity (i.e. trading volume) increases on the day of the NBP communications, most likely due to a decline in foreign exchange market uncertainty (i.e. volatility or risk) because of central bank communication. This issue is further examined empirically in this section below and in the next section.

[Tables 5 and 6 around here]

Finally, we report for comparison the estimates for neutral unexpected announcements introduced in all of the above models. The results are presented in Tables 5 and 6. They show that all estimates of all neutral dummies were never statistically significant in any of the models. This finding means that the negative signs of the dummies from Tables 3a-3b and 4a-4b capture not only the effects relative to the excluded group (i.e. relative to the announcements from the middle basket which are described as having neutral effects).[21] For example, the negative estimates of dummies in the variance equations can be interpreted as evidence that they reduce volatility not only with respect to the excluded neutral announcements but that they also reduce volatility in absolute terms.

4.3. Results for Other Announcements (RM, BOP and AL)

In this section, we discuss the estimation results for the remaining three announcement dummies: reserve money (RM), balance of payments (BOP) and liquid assets and liabilities in foreign currencies (AL).

The first panels in Tables 3a and 3b present the estimates of the surprise announcement dummy variables in the mean equations from the model of the PLN/USD

[21] We thank the Anonymous Referee for drawing our attention to the issue of a possible separation of the effect in the constant from the effect of the announcement coefficient in the regressions for which results are presented in Tables 5 and 6 and in the earlier Tables 3a-3b and 4a-4b. However, because it is not possible to disentangle those effects in a straightforward way, we opted for the modelling approach which we present in this paper.

exchange rate returns, i.e. the estimates from equation (1). As previously, all variants of the model were estimated with all the NBP dummies for t and for $t+1$.

The results on the announcement date for the remaining three dummies show that strongly positive RM and negative AL announcements both depreciated the domestic currency by about 0.60% against the US dollar, while the strongly negative RM and positive BOP and AL announcements have had the opposite impact on PLN/USD returns and caused appreciation by -0.45%, -0.35% and -0.43%, respectively.

On the next day after the announcement, a strongly positive AL announcement further depreciated PLN by about 0.87% against the US dollar and a strongly negative RM announcement appreciated it by about -0.46%. The results for days t and $t+1$ reveal that all announcements had a significant impact on the mean values of foreign exchange returns with a dominance of stronger surprises.

The results from equation (1) reported in Tables 3a and 3b also demonstrate the importance of the EUR/USD exchange rate movements for the PLN/USD exchange rate. The estimated coefficient for the exchange rate is significant and negative, and is similar in all models. It suggests that a 1% increase in the EUR/USD exchange rate nominal value (i.e. euro depreciation against the US dollar) reduces the nominal value of the PLN/USD exchange rate (i.e. appreciates the Polish zloty against the US dollar) by about 0.33% – 0.36%. However, the interest rate differential variable is insignificant**.**

The first panels in Tables 4a and 4b present the estimates of the unexpected announcement variables in the mean equations from the model of the PLN/USD volume of trade percentage changes ($\Delta Volume_t$), i.e. the estimates from equation (3).

On the announcement date (day t), statistically significant results were found for other announcements further to the MS dummy, i.e. for the RM and AL variables. The surprise strongly negative RM and positive AL announcements both increased trading volume by about 32% and 38%, respectively. On the next day (day $t+1$) negative RM announcement

also increased trading volume by about 29%. Therefore, more market activity, as measured by the changes in trading volume, was detected on the day of the announcement, with only one dummy variable significant on the following day. The results suggest that traders pay attention to money supply, reserve money, and also developments in liquid assets and liabilities in foreign currencies in their positioning decisions. The coefficients of all three dummy variables, which had statistically significant estimates, also had only positive signs, which suggests that market activity increases in response to the NBP communication.[22] There is no evidence of statistically significant results for dummy estimates with negative signs in any of the volume models in Tables 4a and 4b.

It is important to emphasize that the pattern of results for the NBP announcements dummy variables in the variant without the GARCH-in-mean component is the same as in Tables 4a and 4b, which further confirms the robustness of our findings (results not reported here but available upon request).

As Tables 3a and 3b show, similarly to the findings for the MS dummy reported in the previous section, on the announcement day the estimates for the remaining three announcement dummy variables in the variance equations, which are statistically significant, also have consistently negative signs, so they all had a significant calming impact on the conditional volatility (i.e. lowering risk) of foreign exchange returns, also suggesting that the central bank communication resulted in a decline in market uncertainty. Overall, on day t all 8 strongly positive and strongly negative dummies were negative and all 8 of them are statistically significant (all at the highest 1% significance level). For the

[22] Furthermore, we investigated the patterns in volume dynamics in two daily sub-periods: before 4:00 PM and after 4:00 PM, in order to check if the volume had been reacting before the NBP communications at 4:00 PM and to understand whether on the NBP announcement days the market activity increased after the announcement had been made relative to the period before 4:00 PM. For this purpose, we summed up all trades in these two intra-daily sub-periods and compared the results for days when the NBP announcements were released *versus* the days without the NBP communication. The total number of all trades on the days of the NBP communication was higher on average by 7.57% than on other days, and was higher by 7.07% in the period before 4:00 PM, but it increased in proportion substantially more in the period after the NBP announcements at 4:00 PM, i.e. by 12.01%. Hence, there is no evidence that the reaction of the volume was materialized predominantly in the earlier part of the day before the NBP announcements were released at 4:00 PM.

medium strength dummies (positive and negative), a further 4 of them are significant and negative. On the next day after the announcement, this effect is very similar and there is evidence that in case of all four dummies there is reduction of market uncertainty. This decline in market volatility could be responsible for the higher trading volume activity reported in Tables 4a and 4b.

Tables 4a-4b present the estimates of the GARCH model for volume of trade percentage changes where the dummy variables are included in the conditional variance function (i.e. equation (4)). On the day of the announcement, similarly to the results for the MS dummy, two other strongly positive and strongly negative announcements (RM and BOP) had a statistically significant effect on the volatility. In all these cases the estimates are negative and they are all significant at the 1% level. The dominance of statistically significant estimates that have negative sign suggests that these announcements have a calming impact on volatility. On the next day, all four strongly positive and strongly negative dummies further affected the conditional volatility of the trading volume, again suggesting existence of the calming effects. In addition, two surprises of medium strength (positive and negative AL) are also statistically significant and with negative signs.

The results in Tables 4a and 4b for RM, BOP and AL confirm the importance of the GARCH-in-mean terms. The estimates of the GARCH-in-mean parameters are mostly statistically significant and they are always negative. They range between -11.14 and 21.97. Therefore, depending upon the announcement employed, a 1% increase in the *standard deviation* of the foreign exchange rate returns brought between an 11.14% and 21.97% decline in the volume of trade. This effect is relatively very strong if it is considered relative to the value of the average (mean) daily percentage change of trading volume (see Table 2).

It is important to note also here that the results in the variant without the GARCH-in-mean component reveal a very similar picture regarding the estimates of the NBP

announcement dummy variables. The pattern of statistical significance of the announcements and their economic significance (i.e. the magnitude of the coefficients) stayed the same for both days t and $t+1$ (results not reported here but available upon request). Hence, we can conclude that our results are robust to different model's specifications with and without the GARCH-in-mean term.

Finally, it should be noted that evidence in Tables 4a and 4b regarding the estimate of the $\sqrt{h_t^{PLN/USD}}$ variable in all models, which is a proxy for exchange rate risk, is negative and consistently significant in almost all cases. This provides direct evidence that the reduction of volatility of the PLN/USD exchange rate has also a positive effect on market activity, i.e. a lower exchange rate risk resulting in an increase of the trading volume.

As in the case of the MS dummy, the estimates for neutral unexpected announcements are never statistically significant in any of the models (see Tables 5 and 6).

In summary, we can conclude after combining our findings all together that the results suggest that during our sample period, central bank communication reduced market uncertainty, which helped increase market activity, measured here by trading volume, hence contributing to market development.

Overall, our results on the returns and volatility are consistent with previous studies on emerging markets summarized in the previous sections. In particular, they are in line with Rozkrut et al. (2007) who reported that verbal comments of policy makers in Poland (and two other CEE central banks) influence the behavior of the currency market. An important exception is that of Serwa (2006), who used a similar sample period (1999-2003) as ours, and who reported evidence that foreign exchange rates do not react to monetary announcements in Poland. However, we found that monetary policy announcements actually did affect foreign exchange rate returns and also their volatility as well as the volatility of the trading volume and, to some extent, also increased the activity of the currency market in our sample period. The difference in results may be driven by different

data sets, methodologies and/or measures of monetary policy used. While Serwa (2006) applied official interest rates and an instrumental variable estimation approach to estimate the effect of surprise changes in the official rate on foreign exchange rate returns, we used monetary aggregate announcements (money supply and reserve money) and others and a GARCH model, which allows us to capture the time-varying volatility in returns and to estimate the volatility effects of central bank announcements. We also used trading volume from the foreign exchange market, which is a novel approach and a new contribution to the literature.

5. Robustness Analysis

In this section, we provide some further estimation results to check the robustness of our findings reported in earlier sections.

5.1. Day of the Week Effects

We first investigate the existence of any possible day of the week effects and we check if they may have had any impact on the estimation results presented so far for models of the volume of trade and exchange rates (with NBP announcements dummies both in the mean equation and in the variance), which are presented in Tables 3a-3b and 4a-4b and in other subsequent tables.

Day of the week effects are tested by introducing dummy variables for individual days separately in all models. Estimation results are presented in Table A2 in the Appendix. They show that there are only 4 cases when the day of the week dummy variables were statistically significant, and all of these effects are present only in the volume of trade models but not in the exchange rate models.[23]

[23] The day of the week effects for volume of trade detected in this study for the PLN/USD exchange rate are very similar to those reported for the EUR/USD exchange rate by Brzeszczyński and Melvin (2006), who found

Out of these 4 cases, 3 dummies are statistically significant when they are added to the mean equation of the volume of trade model. These are dummy variables for: Monday, Tuesday and Friday and their respective parameter estimates are as follows: -17.2220, 40.1730 and -26.7096, which means that on Mondays and Fridays the trading volume was on average lower than on other days of the week, but it was higher on Tuesdays. Therefore, we investigate below the possibility whether this effect detected for the Tuesday dummy may have been responsible for any of the statistically significant estimation results for the NBP announcements dummies presented in Tables 4a and 4b.

The only other dummy variable significant in all subsequent models is a Tuesday dummy in the volume of trade model, when it is introduced in the conditional variance equation. Its estimate, however, is positive, so any of the effects presented in Tables 4a and 4b, where all statistically significant NBP announcement dummies have negative signs and, therefore, have calming effect on the volume of trade volatility, cannot be justified simply by the fact that (some of) those announcements were made on Tuesdays. On the contrary, if the NBP announcement was made on a Tuesday, it appears to counteract the general tendency of an increased volume volatility on that day of the week.

As a further robustness check, we added to the mean equation of the volume of trade model (3) - (4) the statistically significant day of the week dummies, i.e. Monday, Tuesday and Friday, and compared these new estimates with those reported in Tables 4a and 4b. Our conclusions are that the addition of the day of the week dummies did not have a detrimental effect on the estimates in Tables 4a and 4b (on the contrary, it even strengthened some results).

The estimates of all other NBP announcements dummies, which were statistically significant in all subsequent tables, were not affected by the introduction of the day of the week dummy variables.

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positive and statistically significant changes of volume on Tuesdays and negative and statistically significant changes of volume on Fridays in the EUR/USD market.

In summary, we can conclude that our findings are robust to the day of the week effects.

5.2. Evolution of NBP Announcements Effects over Time

The results presented so far show the estimates for the whole sample period, so in this section we analyze the possible evolution of those effects over time, which will allow us to answer the question of whether in this early stage of the development of the newly independent Polish central bank NBP, and the currency market learning about its actions and its communication policy, there have been evident any such learning effects by market investors.

For this purpose we divided the entire sample of 792 observations into 2, 3 and 4 equal sub-samples and estimated all the above models in these shorter sub-periods. The problem with the division into 3 and 4 sub-samples has been, however, that in many cases these sub-periods were so short that they did not include any surprise announcements, so no estimates of the dummy variables could be obtained. Moreover, in these very short samples, containing only 198 or 264 observations, there were also very often problems with convergence of estimation procedures in GARCH models, which is typical in GARCH estimation if the time series are not sufficiently long (it is usually assumed that they should contain at least 400 – 500 observations). Therefore, no such analysis could be conducted in such short 4 sub-periods. However, we were able to do this for 2 equal sub-samples of 396 observations each for the model of volume of trade (i.e. the model (3) - (4) for which results are reported in Tables 4a and 4b).

The first panel in Table A3 in the Appendix presents the estimation results for the full sample and the two sub-samples for those NBP announcements dummies which were statistically significant in the full period in equation (3), which had observations in both of these two sub-periods and when there were no numerical problems with estimation of

parameters of the GARCH equations. It shows clearly that in all cases all the NBP announcement effects strengthened over time as measured by the magnitude of the estimated coefficients and/or their significance level.

We also investigate if the detected evolution effect could have been affected by the growth of the entire Polish foreign exchange market over time. If the currency market in Poland has been growing in size in the analyzed sample period, then the quantity of trades, used as our volume variable in this study, could be rising for precisely that reason. Therefore, we also check also the robustness of the evolution effects in the volume of trade models by adjusting the volume data by the growing size of the market.

The only reliable data about the size of foreign exchange markets around the world is available in the Bank for International Settlements (BIS) triennial surveys of currency market participants. From the BIS report from 2005, we can infer that the Polish foreign exchange market grew from about 5 bn USD to about 6 bn USD in our sample period, i.e. by about 20% (see: Triennial Central Bank Survey (2005)). Hence, we adjusted the volume of trade data by assuming linear growth of the Polish currency market size (in absence of any other data that would suggest any other path of growth than linear) and we re-run all regressions for the volume models with the NBP announcements dummy variables.

The second panel in Table A3 presents estimation results for two sub-samples for the volume models of the PLN/USD foreign exchange volume of trade adjusted by the rate of growth of the entire currency market in Poland. It shows that all parameters, which are statistically significant, are positive, and that they are very similar in size to their counterparts in Tables 4a and 4b. They also have the same magnitude of their values and, more importantly, they exhibit the same pattern of changes towards the second sub-sample as the parameters estimated in models with raw volume.

Hence, we can conclude that, the evolution effects did indeed exist in our sample period, even after controlling for the growing size of the market, and that we found some

evidence suggesting that the currency market in Poland and the foreign exchange investors did undergo a learning process about the NBP policy and over time they started to respond more strongly to the NBP communication. Our results suggest that the impact of the NBP announcements did increase over time as the NBP was maturing as a newly independent central bank.

5.3. Further Robustness Checks

Cheung and Ng (1996) suggest that the failure to include dummy variables, which are significant in the variance equation of an ARCH class model, in the mean equation may affect the estimation results. We re-estimated all such variants as a robustness check for models (1) - (2) and (3) - (4) and the conclusions are as follows: (a) the estimates of the volume variable ($\Delta Volume_t$) in the conditional variance function do not change hardly at all; and (b) the estimates of the dummies in the conditional variance function in all cases change only marginally and they remain significant. What is also important is that all dummies, which are additionally introduced into the mean equation, are not statistically significant there. The estimates from the variants of models with statistically significant dummies included *simultaneously* in the variance and mean equations are very consistent and do not alter the overall picture; hence, we can conclude that all our estimation results are robust and are not influenced by the effect described in Cheung and Ng (1996).[24]

We also re-estimated our GARCH models under different distributional assumptions (Students' *t*, generalized error distribution and others) and the estimates were very similar in terms of both magnitude and statistical significance to those reported here, which were based on the normal distribution using the Bollerslev-Wooldridge standard errors. Hence,

[24] We also analyzed the robustness of these estimates in shorter sub-periods but the results are inconclusive due to a lack of convergence of the estimation procedure in many models resulting from a very small number of observations in the time series that does not allow estimating a GARCH model (i.e. 396 for two equal sub-samples, 199 for four equal sub-samples etc.) All the robustness tests are available from the authors upon request.

we can conclude that all our estimation results are robust to the change in distributional assumption about the error term.

Furthermore, we attempted to check if the impact of the NBP announcements is larger or smaller than, or whether it is affected at all by, the corresponding announcements of the European Central Bank (ECB). However, we could construct only one ECB dummy for the ECB money supply variable (MS) due to problems with ECB data availability for other dummies.[25] Therefore, we present the estimation results for models with the NBP and ECB dummy MS in the Appendix as an illustration only. For the sake of comparability of estimates, we used the same definition of the unexpected ECB announcements for the MS variable as in the case of the NBP dummy variables (i.e. deviation from 3-months moving average). For the unexpected strongly negative announcement of the ECB money supply, the dummy did not have any observations in our sample period (hence, it is not used in the estimations). Table A4 in the Appendix presents the results for the exchange rate returns models and Table A5 the volume of trade models.

Estimation results in Tables A4 and A5 show that the ECB unexpected announcements are in most cases not statistically significant. Moreover, in the instances where they are significant, their introduction to the models did not materially alter the estimates of the NBP dummies. Therefore, the ECB unexpected announcements did not appear to affect the pattern of the estimates of the NBP dummy variables.

6. Investment Strategy

The findings presented in previous sections about the impact of the NBP communication on the movements of the PLN/USD foreign exchange rate show evidence of

[25] The data for all four corresponding announcements (MS, RM, BOP and AL) are available from the ECB, however it cannot be verified with absolute certainty for this historical period time in years 2000 – 2003 exactly *when* those announcements were made for the RM, BOP and AL variables. Hence, we opted to present the results only for the MS dummy.

appreciation and depreciation effects in response to some of the NBP announcements, in particular those which have been classified as strongly positive and strongly negative surprises.

Therefore, in this section we investigate in more detail whether events such as the release of new monetary figures by the NBP may create profit opportunities for the currency market investors.

We simulate a hypothetical investment strategy and analyze the possible profits and losses from trades based on the statistically significant estimates (at the level of $p < 0.01$) of the dummies from Tables 3a and 3b, i.e. from the PLN/USD exchange rate model.

Due to the fact that the NBP announcements were always made at 4:00 PM, in this section we use the intradaily data for the PLN/USD exchange rate to measure the profitability of trades based on the dummy variables, which were statistically significant on day t and day $t+1$ (see results in Tables 3a and 3b). Another reason why we use intradaily frequency and investigate in such detail the changes in the PLN/USD exchange rate over these very short periods of time is that any such investigation should consider investment horizons finer than just 1 day intervals. This is because many traders are very likely to transact within rather short time horizons in response to such news as public information contained in the central bank announcements.

Our trading rule is simple. We assume that an investor opens a *long position* in the PLN/USD exchange rate on the day when there is a NBP announcement, which was found in Tables 3a and 3b to be statistically significant (at the level $p < 0.01$) and had a *positive* sign (implying a prediction of a depreciation of the PLN), or an investor opens a *short position* in the PLN/USD when there is an announcement, which in Tables 3a and 3b was found to be statistically significant (at the level $p < 0.01$) and had a *negative* sign (implying a prediction of an appreciation of the PLN). The positions are allocated leverage in proportion strictly depending on the value of the estimated parameter (i.e. the higher the absolute

value of the estimate the higher the leverage). These positions are closed at the end of the investment horizon. As a robustness check, we investigate the performance of this trading strategy for a variety of different investment horizons, which allows us to present a broader spectrum of results.

Table 7 presents profits and losses from such a strategy (measured in basis points, bps) for trades that are executed based on the information about statistically significant NBP announcements dummies on day t (Panel A) and on day $t+1$ (Panel B) for different investment horizons and different levels of trading costs.

[Table 7 around here]

In Panel A, the trading horizons are the intervals of time between the NBP announcements (made always at 4:00 PM CET) and the following points of time denoted as: '+1 hour', '+3 hours', 'until the end of day t', '+16 hours', '+20 hours', '+24 hours' and 'until the end of day $t+1$'.

The intervals denoted as 'until the end of day t' and 'until the end of day $t+1$' vary in length because they depend on the exact time of the last transaction in the PLN/USD market on a specific day, as recorded in our database obtained from Reuters. For example, if the last transaction occurred at 9:45 PM CET, the investment horizon is 5 hours and 45 minutes. Obviously, in the foreign exchange market the transactions may be executed at any time and, thus, those times will be naturally different every day. Other intervals are fixed in their length, e.g. in the interval denoted as '+24 hours' the profits or losses from the strategy are measured always between 4:00 PM on the announcement days and 4:00 PM on the following day.

In Panel B, the trading horizons are the intervals of time between the first trade on day $t+1$, as recorded in Reuters database, and the following points of time denoted as: 'until

10:00 AM', '10:00 AM +3h', '10:00 AM +6h', '10:00 AM +9h', 'until the end of day $t+1$'. In this case, all intervals vary in length because they now depend on the exact time of the first and last transactions in the PLN/USD market on a specific day, as reported by Reuters. For example, if on a particular day the first trade was made at 6:35 AM and the last one at 10:58 PM, the investment horizon used in our calculations is 16 hours and 23 minutes.

In the simulation of our investment strategy we assumed that those trades that are based on the NBP announcements that were made just before the weekend, i.e. on Friday at 4:00 PM, have the investment horizon only until the end of that day since it is very unlikely that currency market traders will keep their positions open in the FX market over the weekend and will want to expose their investments to a variety of risks, which are related to this non-trading (weekend) period. Therefore, in the simulation of trades based on the dummies which were statistically significant on day t and when the NBP announcement was made on Friday the longest trading horizon is the end of day t (i.e. last trade on Friday). Otherwise, the longest investment horizon is end of day $t+1$.

For the dummies significant on day $t+1$, we also assume the longest investment horizon to be the end of day $t+1$ with the exclusion of trades that are based on the NBP announcement made on Fridays (since the simulation would have to measure the performance of such an investment either on a Saturday, when currency market activity is extremely low, or after the weekend on a Monday).

We also take into account the cost of trading in the execution of such an investment strategy. In the foreign exchange market the trading cost is a bid-ask spread, and for the PLN/USD exchange rate the typical spread is about 10 bps (or less), but as a robustness check we also assume higher spreads of 25 bps and 50 bps.

Although a realistic cost of trading for PLN/USD is 10 bps, it needs to be emphasized that many professional currency traders are able to 'time' the markets by using different short-term momentum strategies (e.g. based on such indicators as Relative Strength Index

(RSI) or Moving Average Convergence Divergence (MACD) etc.) and in their transactions they can buy / sell currencies at the bid and ask prices which are slightly lower / higher by taking advantage of short-term trends and price movements when they execute their trades e.g. several seconds earlier or later than they would normally do, if they did not use any technical analysis tools. This means that they are able to completely offset the trading cost (or even more than compensate it) and, hence, the cost of trading of 0 bps, which we also investigate in Table 7, is not necessarily only a theoretical calculation but is in fact quite realistic for many foreign exchange investors.

The results in Table 7 demonstrate that such strategy would be profitable in most of the reported investment horizons. The profits are highest, however, in shorter horizons, i.e. for '+3 hours' on day t and for '10:00 AM +3h' for day $t+1$. For the trading costs equal to 10 bps, the only negative performance is found for only the 3 longest trading horizons on day t (and, naturally, for more horizons in cases of very high, and less realistic in practice, costs of trading). On day $t+1$ the trades executed in all horizons were profitable for all levels of transaction costs.

In addition, a diversification of investment strategy for all trading horizons (assuming that a trader opens 12 positions of equal value and closes them sequentially according to the subsequent horizons) would yield positive average profits across all costs of trading (ranging from 354.50 bps for a zero transaction costs case to 139.42 bps for the highest cost of 50 bps with 311.42 bps for the case of most realistic cost of 10 bps).

In summary, we analyzed a variety of different investment horizons, and we detected a clear and consistent pattern of possible profit opportunities for the investors who responded to the NBP announcements, for which we found statistically significant estimates of the NBP announcements dummy variables. This is an important finding that may have practical implications for currency market investors.

7. Discussion

Our results presented in this paper suggest that Polish central bank announcements significantly affected investor behaviour during our sample period. We have a total of 150 announcements for 4 dummy variables which we investigated in this study (MS, RM, BOP and AL) and statistically significant results for respective dummies were found in the case of all of them in various models, which we analyzed (for both volume of trade and for the foreign exchange rate). In addition, all central bank announcements seemed equally important for investors. We have the following number of significant announcements: 12, 14, 9 and 14 for: MS, RM, BOP and AL dummy variables (for time t and $t+1$), respectively, so no central bank announcement is particularly more often significant than others.

Another important observation is that strongly positive and strongly negative announcements were more often significant than the announcements of medium strength (i.e. positive and negative ones). Overall, there was a clear dominance of strongly positive and strongly negative announcements over the positive and negative announcements (in total: 30 *versus* 19).

Table 8 presents a more detailed breakdown of statistically significant estimation results for dummy variables of different strengths. It shows further that NBP announcement dummies of the highest strength (i.e. strongly positive and strongly negative) were significant considerably more often at the 1% level than the other dummies of medium strength for both t and $t+1$. The economic significance of strongly positive and strongly negative announcements (i.e. estimated coefficients) is much larger than those of medium strength.

[Table 8 around here]

Overall, our results show that investors react to surprise central bank announcements significantly and they consider all announcements equally, but pay more attention and are more sensitive to relatively larger (i.e. strongly positive or strongly negative) surprises.

Another key finding in this study is that when the same-day effects were estimated for the conditional variance, in either volume models or exchange rate models, they are always negative and significant. We interpret this as the calming effect of public announcements. However, it is possible that such a reduction of volatility is related simply to the fact that significantly fewer people transacted on days in which the monetary authority made an announcement at 4:00 PM in the afternoon.[26] Below we investigate this issue.

This question can be answered by directly analyzing the estimates in Tables 3a-3b, and 4a-4b. Tables 4a and 4b present estimation results for dummy variables from the mean equation of the volume of trade models where the dependent variable is the number of trades in the PLN/USD. We compare these results with the statistically significant estimates of the dummies from the variance equations presented in Tables 3a-3b and 4a-4b.

The estimation results point towards a clear conclusion that there is no case where any dummy variable that is statistically significant in any of the variance equations either in time t or time $t+1$ is also statistically significant and *negative* as a corresponding estimate in the mean equation of the volume of trade model (in Tables 4a or 4b).

On the contrary, for the estimates that were statistically significant in Tables 3a-3b and 4a-4b (and they always have *negative* signs) the corresponding estimates of dummies in the volume of trade models in Tables 4a and 4b that were also statistically significant, have *positive* signs (i.e. strongly positive MS in time t, strongly negative RM in time t and strongly negative MS in time $t+1$).

[26] We would like to thank the Anonymous Referee for this suggestion as well as for other very helpful comments about the design and the structure of our models and about other important issues which motivated us to conduct various types of robustness checks of our empirical findings, which we presented in previous sections of this paper.

Hence, there is clearly no evidence that the statistically significant calming effects identified in the variance equations coincide with the statistically significant decrease of trading volume on those days. In other words, there is no evidence that there was a decreased market activity and that fewer people transacted on those days.[27]

8. Conclusions and Policy Implications

In this paper, we employed a unique database obtained directly from Reuters electronic brokerage platform for currency trading and estimate the impact of central bank announcements on investor behavior by examining changes in foreign exchange market returns and trading volume in the Polish market. The sample period studied (2000-2003) is interesting as it captures the time period when the National Bank of Poland had gained its independence and was experiencing key institutional developments as the Monetary Policy Council was established in 1998 and a new inflation targeting regime was introduced in 1999.

We have provided evidence from foreign exchange rate returns and volume of trade models and found that central bank announcements affect the returns and trading volume, and also the conditional volatilities of both those variables. The conditional volatility of the returns consistently declines in all cases, whenever any announcement was statistically significant, suggesting that the Polish central bank announcements had resulted in a decline in the risk (measured here by the conditional variance) in the foreign exchange market.

We interpret these negative effects in variances as calming effects of the NBP communication. Next, we analyzed effects in mean equations and found that central bank

[27] The market in the PLN/USD foreign exchange rate is usually active until the late evening hours, sometimes even until as late as 10:00 – 11:00 PM local time (CET), so even if the NBP announcements are made at 4:00 PM in the afternoon, the traders still have a few hours to transact in this currency during the same day (and, in addition, those trades can be executed not only by local traders in banks in Poland, or in other countries in Europe, but also by traders located in the USA which is the market that is very active during this part of the day which is, in fact, a noon and an afternoon of the working day in New York), which we believe explains our result.

communication affects the currency market volume of trade. An important finding is that trading volume always rises on the days of NBP announcements, whenever any announcement was statistically significant, suggesting that there had been an increase in investors' trading activity when such important information is revealed by the central bank.

In addition, we have also illustrated that the decline in uncertainty contributed to an increase in trading volume, suggesting further that central bank communication can be useful for improving market development in terms of higher trading activity and reducing market volatility in the early years of financial market development.

All our estimation results are robust to day of the week effects which were either not statistically significant in any of the exchange rate models or did not affect the estimates of the NBP announcement dummies in other (limited) cases in the volume of trade models.

We also investigated the evolution of NBP announcements effects over time in two equal sub-periods and we found evidence that these effects did indeed strengthen. Hence, we can conclude that that the currency market in Poland and the foreign exchange investors did undergo a learning process about the NBP policy and over time they started to respond more strongly to the NBP communication. The impact of the NBP announcements did increase over time as the NBP was maturing as a newly independent central bank.

Finally, we explored possible profit opportunities for currency market investors based on the statistically significant estimates of the NBP announcements dummy variables in the exchange rate models, which can be used as predictors of appreciation and depreciation of the PLN/USD exchange rate. We found that for a number of different investment horizons and different levels of transaction costs such profit opportunities did in fact exist.

The results presented in this study support arguments that investors in emerging financial markets may react differently to those in industrial countries. However, we also presented evidence about the evolution of those responses over time as the Polish central bank NBP was maturing, the Polish monetary authorities were gaining strength, the

confidence of investors was increasing and as Poland was gradually becoming more integrated with the global financial system towards joining the European Union in the year 2004.

Our findings also have broader policy and theoretical implications. We presented evidence showing that central bank announcements in newly established emerging economy going through significant institutional developments and monetary policy changes may significantly affect trading volume by influencing investors' decisions in the foreign exchange market. One implication of this result is that nominal exchange rate and trading volume changes due to central bank communication may signal information about the transparency or predictability of an independent central bank and its actions during its early years. Furthermore, the empirical link provided here between monetary policy announcements, including those of money supply and reserve money, and exchange rate changes may help better understand how monetary transmission mechanism works in emerging economies. The significance of public information arrival, contained in central bank announcements in this study, supports theoretical exchange rate models that emphasize the importance of the arrival of public information as well.

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Table 1a. National Bank of Poland (NBP) announcements in the period from August 2000 to September 2003.

	Number of announcements	Frequency	Other comments
Money Supply (*MS*)	38	Monthly	Usually middle of the month
Reserve Money (*RM*)	38	Monthly	Usually 5th-7th calendar day of every month
Balance of Payments (*BOP*)	38	Monthly	Usually end of every month
Liquid Assets and Liabilities in Foreign Currencies (*AL*)	36	Monthly	Usually end of every month

Table 1b. Numbers of National Bank of Poland (NBP) announcements with different strengths in the period from August 2000 to September 2003 (based on division into baskets according to their deviations from their respective moving averages).

	strongly positive	positive	neutral	negative	strongly negative	Sum:
Money Supply (*MS*)	5	18	7	7	1	38
Reserve Money (*RM*)	3	11	15	8	1	38
Balance of Payments (*BOP*)	1	8	21	7	1	38
Liquid Assets and Liabilities in Foreign Currencies (*AL*)	1	8	22	3	2	36

Table 2. Descriptive statistics for returns of the PLN/USD exchange rate and percentage changes of the PLN/USD volume of trade, daily data (August 2000 – September 2003).

	Returns of the PLN/USD exchange rate	Percentage changes of the PLN/USD volume of trade
Mean	0.0024	10.5415
Median	-0.0483	-0.5103
Maximum	4.3494	268.8525
Minimum	-2.6184	-74.2072
Std. Dev.	0.6551	52.0938
Skewness	0.7388	1.4949
Kurtosis	6.7863	6.1273
Jarque-Bera	545.1399	617.7465
Probability	0.0000	0.0000

Table 3a. Results for foreign exchange rate returns models on day *t*.

This table reports estimates of dummy variables for the NBP announcements days with unexpected announcements of different strength on day *t* in the mean equation (1):

$$r_t^{PLN/USD} = \alpha_0 + \alpha_1 \cdot \Delta Volume_{t-1} + \alpha_2 \cdot r_t^{EUR/USD} + \alpha_3 \cdot INTDIFF_t + \sum_{s=4}^{7} \alpha_s \cdot DUM_{s,t} + \xi_t$$

and in the conditional variance equation (2):

$$h_t^{PLN/USD} = \beta_0 + \beta_1 \cdot \xi_{t-1}^2 + \beta_2 \cdot h_{t-1} + \beta_3 \cdot \Delta Volume_{t-1} + \sum_{p=4}^{7} \beta_p \cdot DUM_{p,t}$$

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

Eq.	**On day *t***				
	Mean equation:				
(1)	$\hat{\alpha}_0$	0.050414 (0.056781)	0.042201 (0.053866)	0.171196 (0.104473)	0.161437 (0.191428)
(1)	$\hat{\alpha}_1$	0.000258 (0.000497)	0.000317 (0.000535)	-0.000068 (0.000420)	-0.000123 (0.000418)
(1)	$\hat{\alpha}_2$	-0.336062 *** (0.034002)	-0.340842 *** (0.035376)	-0.360701 *** (0.032821)	-0.349204 *** (0.039413)
(1)	$\hat{\alpha}_3$	-0.004932 (0.005957)	-0.004450 (0.005626)	-0.006350 (0.005542)	-0.004754 (0.006038)
	Unexpected announcement:	**Money Supply (*MS*)**	**Reserve Money (*RM*)**	**Balance of Payments (*BOP*)**	**Liquid Assets and Liabilities (*AL*)**
(1)	$\hat{\alpha}_4$ **strongly positive**	0.296999 (0.207050)	0.596598 ** (0.251385)	0.285336 (0.288972)	0.538363 (0.720052)
(1)	$\hat{\alpha}_5$ **positive**	0.064169 (0.105602)	-0.197900 (0.129611)	-0.350221 * (0.188160)	-0.431247 * (0.220366)
(1)	$\hat{\alpha}_6$ **negative**	0.000741 (0.065825)	0.049419 (0.185389)	0.137488 (0.330194)	0.599481 * (0.308985)
(1)	$\hat{\alpha}_7$ **strongly negative**	0.203167 *** (0.054875)	-0.454506 *** (0.112755)	0.179259 (0.247692)	0.523365 (0.589494)

(continued on next page)

Table 3a (continued):

Eq.	On day t				
	Conditional variance equation:				
(2)	$\hat{\beta}_0$	0.337711 ** (0.150453)	0.334222 *** (0.041169)	0.233439 *** (0.042042)	0.339365 *** (0.039561)
(2)	$\hat{\beta}_1$	0.053279 (0.050794)	0.057582 (0.057029)	0.065978 (0.050088)	0.062433 (0.047513)
(2)	$\hat{\beta}_2$	0.289662 (0.186281)	-	-	-
(2)	$\hat{\beta}_3$	0.000095 (0.000269)	0.000222 (0.001539)	0.000982 (0.001528)	0.000285 (0.001299)
	Unexpected announcement:	**Money Supply (MS)**	**Reserve Money (RM)**	**Balance of Payments (BOP)**	**Liquid Assets and Liabilities (AL)**
(2)	$\hat{\beta}_4$ **strongly positive**	-0.304042 *** (0.105862)	-0.223573 *** (0.079967)	-0.235666 *** (0.041044)	-0.361235 *** (0.024896)
(2)	$\hat{\beta}_5$ **Positive**	-0.289206 *** (0.084052)	-0.202996 *** (0.074938)	-0.014677 (0.076921)	0.156610 (0.260171)
(2)	$\hat{\beta}_6$ **negative**	-0.453462 *** (0.041805)	-0.120253 (0.160663)	0.355935 (0.269200)	-0.284445 *** (0.039322)
(2)	$\hat{\beta}_7$ **strongly negative**	-0.519109 *** (0.063367)	-0.413447 *** (0.113611)	-0.246522 *** (0.037370)	-0.347637 *** (0.029454)
		Q(10) = 11.592 (p = 0.313) LM(10) = 1.411846 (p = 0.1701) Log likelihood = -720.1509	Q(10) = 5.0285 (p = 0.832) LM(10) = 0.488563 (p = 0.8981) Log likelihood = -705.6794	Q(10) = 4.1996 (p = 0.898) LM(10) = 0.292589 (p = 0.9829) Log likelihood = -696.1018	Q(10) = 12.145 (p = 0.275) LM(10) = 1.246193 (p = 0.2575) Log likelihood = -708.2499

Notes: Values of the standard errors in the brackets. The value of the Q(10) test for autocorrelation, the LM(10) test for any remaining ARCH effects and the log likelihood are reported in the bottom rows of every panel. Number of equation in the first column indicates whether the estimated parameters relate to the variables in the mean equation or in the conditional variance equation of the GARCH model.

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

Table 3b. Results for foreign exchange rate returns models on day *t+1*.

This table reports estimates of dummy variables for the NBP announcements days with unexpected announcements of different strength on day *t+1* in the mean equation (1):

$$r_t^{PLN/USD} = \alpha_0 + \alpha_1 \cdot \Delta Volume_{t-1} + \alpha_2 \cdot r_t^{EUR/USD} + \alpha_3 \cdot INTDIFF_t + \sum_{s=4}^{7} \alpha_s \cdot DUM_{s,t} + \xi_t$$

and in the conditional variance equation (2):

$$h_t^{PLN/USD} = \beta_0 + \beta_1 \cdot \xi_{t-1}^2 + \beta_2 \cdot h_{t-1} + \beta_3 \cdot \Delta Volume_{t-1} + \sum_{p=4}^{7} \beta_p \cdot DUM_{p,t}$$

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

Eq.	**On day *t+1***				
	Mean equation:				
(1)	$\hat{\alpha}_0$	0.055755 (0.054487)	0.038627 (0.054367)	0.196612 (0.156482)	0.203355 * (0.110651)
(1)	$\hat{\alpha}_1$	0.000227 (0.000543)	0.000264 (0.000547)	-0.000136 (0.000448)	-0.000168 (0.000467)
(1)	$\hat{\alpha}_2$	-0.340290 *** (0.035708)	-0.329301 *** (0.036203)	-0.341527 *** (0.033941)	-0.345740 *** (0.033839)
(1)	$\hat{\alpha}_3$	-0.005868 (0.005719)	-0.004575 (0.005738)	-0.007736 (0.005667)	-0.005534 (0.006266)
	Unexpected announcement:	**Money Supply (*MS*)**	**Reserve Money (*RM*)**	**Balance of Payments (*BOP*)**	**Liquid Assets and Liabilities (*AL*)**
(1)	$\hat{\alpha}_4$ **strongly positive**	0.169235 (0.284803)	-0.198571 (0.659580)	0.052185 (0.912403)	0.873658 *** (0.272143)
(1)	$\hat{\alpha}_5$ **positive**	-0.049607 (0.121929)	0.010662 (0.114996)	0.279361 (0.378729)	0.270267 (0.252208)
(1)	$\hat{\alpha}_6$ **negative**	-0.098928 (0.262876)	0.221380 (0.335618)	0.307224 (0.254786)	0.031378 (0.381722)
(1)	$\hat{\alpha}_7$ **strongly negative**	-1.024195 *** (0.030366)	-0.466825 *** (0.064463)	-0.122469 (0.636448)	0.162017 (0.473790)

(continued on next page)

Table 3b (continued):

Eq.	On day *t+1*				
	Conditional variance equation:				
(2)	$\hat{\beta}_0$	0.327010 *** (0.034991)	0.327984 *** (0.034434)	0.279546 ** (0.118412)	0.339091 *** (0.099886)
(2)	$\hat{\beta}_1$	0.064481 (0.053958)	0.068877 (0.053636)	0.052365 (0.061674)	0.046139 (0.057792)
(2)	$\hat{\beta}_2$	-	-	0.321726 (0.270833)	0.253290 (0.221159)
(2)	$\hat{\beta}_3$	0.000382 (0.001518)	0.000273 (0.001484)	0.000575 (0.001164)	0.001122 (0.001038)
	Unexpected announcement:	**Money Supply (*MS*)**	**Reserve Money (*RM*)**	**Balance of Payments (*BOP*)**	**Liquid Assets and Liabilities (*AL*)**
(2)	$\hat{\beta}_4$ **strongly positive**	0.051632 (0.149720)	0.545413 (0.529888)	-0.397196 *** (0.044378)	-0.388755 *** (0.080676)
(2)	$\hat{\beta}_5$ **positive**	-0.096604 (0.089588)	-0.243365 *** (0.057401)	-0.360974 *** (0.055480)	-0.321466 *** (0.045136)
(2)	$\hat{\beta}_6$ **negative**	0.131669 (0.218772)	0.342575 (0.424544)	-0.221037 ** (0.106676)	-0.305305 * (0.175731)
(2)	$\hat{\beta}_7$ **strongly negative**	-0.348395 *** (0.038050)	-0.362330 *** (0.091483)	-0.426933 *** (0.039957)	-0.356986 *** (0.049574)
		Q(10) = 4.6586 (p = 0.863) LM(10) = 1.334156 (p = 0.2076) Log likelihood = -704.7330	Q(10) = 4.9874 (p = 0.835) LM(10) = 0.691786 (p = 0.7327) Log likelihood = -702.1462	Q(10) = 6.4297 (p = 0.696) LM(10) = 1.151769 (p = 0.3205) Log likelihood = -713.9327	Q(10) = 10.249 (p = 0.331) LM(10) = 0.806134 (p = 0.6229) Log likelihood = -703.3887

Notes: Values of the standard errors in the brackets. The value of the Q(10) test for autocorrelation, the LM(10) test for any remaining ARCH effects and the log likelihood are reported in the bottom rows of every panel. Number of equation in the first column indicates whether the estimated parameters relate to the variables in the mean equation or in the conditional variance equation of the GARCH model.

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

Table 4a. Results for the volume of trade (percentage change) models on day t.

This table reports estimates of dummy variables for the NBP announcements days with unexpected announcements of different strength on day t in the mean equation (3):

$$\Delta Volume_t = \alpha_0 + \alpha_1 \cdot r_{t-1}^{PLN/USD} + \alpha_2 \cdot \sqrt{h_t^{PLN/USD}} + \sum_{s=3}^{6} \alpha_s \cdot DUM_{s,t} + \xi_t$$

and in the conditional variance equation (4):

$$h_t^{volume} = \beta_0 + \beta_1 \cdot \xi_{t-1}^2 + \beta_2 \cdot h_{t-1} + \beta_3 \cdot r_{t-1}^{PLN/USD} + \sum_{p=4}^{7} \beta_p \cdot DUM_{p,t}$$

from the GARCH model (3) - (4) of the PLN/USD volume of trade percentage changes.

Eq.	**On day *t***				
	Mean equation:				
(3)	$\hat{\alpha}_0$	23.04539 *** (5.730667)	17.47225 *** (6.197713)	20.75458 *** (5.494284)	21.78080 *** (4.840040)
(3)	$\hat{\alpha}_1$	3.889681 * (2.346580)	4.921102 ** (2.413227)	3.326238 (2.207625)	4.496834 *** (1.713976)
(3)	$\hat{\alpha}_2$	-19.70514 ** (8.974566)	-11.14013 (9.451737)	-17.10362 ** (8.553098)	-18.66156 ** (7.329174)
	Unexpected announcement:	**Money Supply (*MS*)**	**Reserve Money (*RM*)**	**Balance of Payments (*BOP*)**	**Liquid Assets and Liabilities (*AL*)**
(3)	$\hat{\alpha}_3$ **strongly positive**	18.44304 ** (8.072167)	-7.120074 (9.878211)	4.837109 (65.78572)	-25.50667 (25.74529)
(3)	$\hat{\alpha}_4$ **Positive**	-12.02899 (7.684704)	0.886836 (11.11062)	5.175269 (21.92043)	38.46860 ** (16.54673)
(3)	$\hat{\alpha}_5$ **negative**	-4.290514 (31.30227)	19.87689 (15.70590)	19.58404 (13.36013)	-26.63974 (18.57744)
(3)	$\hat{\alpha}_6$ **strongly negative**	-25.92982 (110.8539)	31.57786 *** (4.329668)	-38.09548 (45.61772)	40.96724 (29.85069)

(continued on next page)

Table 4a (continued):

Eq.	On day t				
	Conditional variance equation:				
(4)	$\hat{\beta}_0$	1193.164 *** (199.6763)	1670.550 *** (142.2296)	1469.826 *** (118.8482)	1566.930 *** (165.5930)
(4)	$\hat{\beta}_1$	0.263912 *** (0.044763)	0.268485 *** (0.090932)	0.266339 *** (0.041060)	0.246403 *** (0.088980)
(4)	$\hat{\beta}_2$	0.101710 (0.105034)	-	-	-
(4)	$\hat{\beta}_3$	75.96113 (156.7567)	382.9162 ** (186.0196)	275.5187 ** (126.8411)	61.98665 (203.2324)
	Unexpected announcement:	**Money Supply (MS)**	**Reserve Money (RM)**	**Balance of Payments (BOP)**	**Liquid Assets and Liabilities (AL)**
(4)	$\hat{\beta}_4$ **strongly positive**	-1633.327 *** (337.9631)	-1657.062 *** (151.1809)	-333.2671 (9011.827)	-26.33892 (794.0803)
(4)	$\hat{\beta}_5$ **positive**	-1009.098 *** (369.2228)	-755.9774 * (438.1545)	1422.305 (1840.030)	390.0906 (1384.454)
(4)	$\hat{\beta}_6$ **negative**	2320.286 (2023.475)	1914.343 (1431.36)	-494.6698 (1038.535)	-129.9643 (679.1327)
(4)	$\hat{\beta}_7$ **strongly negative**	-227.3521 (5448.854)	-1392.842 *** (175.9095)	-1529.846 *** (154.6102)	-31.88864 (1329.626)
		Q(10) = 4.2372 (p = 0.120) LM(10) = 0.408990 (p = 0.9427) Log likelihood = -4091.128	Q(10) = 4.6899 (p = 0.196) LM(10) = 0.676120 (p = 0.7473) Log likelihood = -4112.028	Q(10) = 6.4534 (p = 0.374) LM(10) = 0.510802 (p = 0.8832) Log likelihood = -4108.896	Q(10) = 7.3562 (p = 0.289) LM(10) = 0.408547 (p = 0.9429) Log likelihood = -4103.452

Notes: Values of the standard errors in the brackets. The value of the Q(10) test for autocorrelation, the LM(10) test for any remaining ARCH effects and the log likelihood are reported in the bottom rows of every panel. Number of equation in the first column indicates whether the estimated parameters relate to the variables in the mean equation or in the conditional variance equation of the GARCH model.

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

Table 4b. Results for the volume of trade (percentage change) models on day *t+1*.

This table reports estimates of dummy variables for the NBP announcements days with unexpected announcements of different strength on day *t+1* in the mean equation (3):

$$\Delta Volume_t = \alpha_0 + \alpha_1 \cdot r_{t-1}^{PLN/USD} + \alpha_2 \cdot \sqrt{h_t^{PLN/USD}} + \sum_{s=3}^{6} \alpha_s \cdot DUM_{s,t} + \xi_t$$

and in the conditional variance equation (4):

$$h_t^{volume} = \beta_0 + \beta_1 \cdot \xi_{t-1}^2 + \beta_2 \cdot h_{t-1} + \beta_3 \cdot r_{t-1}^{PLN/USD} + \sum_{p=4}^{7} \beta_p \cdot DUM_{p,t}$$

from the GARCH model (3) - (4) of the PLN/USD volume of trade percentage changes.

Eq.	**On day *t+1***				
	Mean equation:				
(3)	$\hat{\alpha}_0$	21.92496 *** (3.984464)	19.91369 *** (4.826570)	21.46183 *** (5.069143)	23.95733 *** (3.825664)
(3)	$\hat{\alpha}_1$	3.630350 ** (1.783016)	4.428460 ** (2.222635)	4.719162 ** (2.182056)	4.151796 ** (1.715350)
(3)	$\hat{\alpha}_2$	-18.35161 *** (5.869164)	-15.81085 ** (7.533660)	-17.55960 ** (7.893278)	-21.96662 *** (5.794426)
	Unexpected announcement:	**Money Supply (*MS*)**	**Reserve Money (*RM*)**	**Balance of Payments (*BOP*)**	**Liquid Assets and Liabilities (*AL*)**
(3)	$\hat{\alpha}_3$ **strongly positive**	-13.32158 (14.26268)	-0.568648 (19.10034)	-63.43110 (57.52240)	-2.896642 (3.456016)
(3)	$\hat{\alpha}_4$ **positive**	-6.606596 (7.783051)	6.467447 (11.55464)	14.00297 (9.559686)	0.639041 (11.28417)
(3)	$\hat{\alpha}_5$ **negative**	17.81411 (19.88561)	29.13365 * (15.75412)	-5.007828 (8.512196)	0.899323 (12.48134)
(3)	$\hat{\alpha}_6$ **strongly negative**	23.33104 *** (5.092421)	14.34723 (61.24580)	-24.53733 (58.55872)	15.31677 (33.22114)

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Table 4b (continued):

Eq.	On day *t+1*				
	Conditional variance equation:				
(4)	$\hat{\beta}_0$	1527.012 *** (138.1736)	994.4989 *** (171.4258)	1415.079 *** (181.0571)	1344.115 **** (232.1394)
(4)	$\hat{\beta}_1$	0.254579 *** (0.095084)	0.251314 *** (0.039900)	0.270622 *** (0.047464)	0.290202 *** (0.078924)
(4)	$\hat{\beta}_2$	-	0.315820 *** (0.080866)	0.129131 * (0.069902)	0.084959 (0.4946)
(4)	$\hat{\beta}_3$	312.1672 (194.5050)	174.3411 (129.1036)	369.8170 *** (135.3813)	135.8383 (189.4862)
	Unexpected announcement:	**Money Supply (*MS*)**	**Reserve Money (*RM*)**	**Balance of Payments (*BOP*)**	**Liquid Assets and Liabilities (*AL*)**
(4)	$\hat{\beta}_4$ **strongly positive**	-462.1015 (766.5051)	-697.3829 (2236.985)	-380.3082 (9656.610)	-903.8164 ** (403.1368)
(4)	$\hat{\beta}_5$ **positive**	-531.4078 (409.4024)	3.868011 (1090.368)	-738.4327 (979.1635)	-1133.503 *** (328.4502)
(4)	$\hat{\beta}_6$ **negative**	692.0869 (745.8759)	1390.120 (2222.501)	-1218.049 (831.9350)	-964.4794 *** (192.5440)
(4)	$\hat{\beta}_7$ **strongly negative**	-1529.441 *** (316.3183)	-2390.543 *** (135.2899)	-1944.087 *** (176.1636)	1372.325 (3087.387)
		Q(10) = 6.4625 (p = 0.167) LM(10) = 0.408992 (p = 0.9427) Log likelihood = -4113.605	Q(10) = 5.6386 (p = 0.343) LM(10) = 0.429894 (p = 0.9323) Log likelihood = -4117.180	Q(10) = 6.0041 (p = 0.111) LM(10) = 0.650906 (p = 0.7703) Log likelihood = -4091.252	Q(10) = 5.1047 (p = 0.403) LM(10) = 0.212579 (p = 0.9952) Log likelihood = -4086.446

Notes: Values of the standard errors in the brackets. The value of the Q(10) test for autocorrelation, the LM(10) test for any remaining ARCH effects and the log likelihood are reported in the bottom rows of every panel. Number of equation in the first column indicates whether the estimated parameters relate to the variables in the mean equation or in the conditional variance equation of the GARCH model.

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

Table 5. Results for foreign exchange rate returns models with neutral announcements on days *t* and *t+1*.

This table reports estimates of dummy variables for the NBP announcements days with unexpected announcements of neutral strength in the mean equation (1):

$$r_t^{PLN/USD} = \alpha_0 + \alpha_1 \cdot \Delta Volume_{t-1} + \alpha_2 \cdot r_t^{EUR/USD} + \alpha_3 \cdot INTDIFF_t + \alpha_4 \cdot DUM_{s,t} + \xi_t$$

and in the conditional variance equation (2):

$$h_t^{PLN/USD} = \beta_0 + \beta_1 \cdot \xi_{t-1}^2 + \beta_2 \cdot h_{t-1} + \beta_3 \cdot \Delta Volume_{t-1} + \beta_4 \cdot DUM_{p,t}$$

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

Eq.	**On day *t***				
	Mean equation:				
(1)	$\hat{\alpha}_0$	0.052298 (0.053873)	0.052632 (0.054970)	0.049001 (0.055288)	0.053675 (0.056301)
(1)	$\hat{\alpha}_1$	0.000202 (0.000575)	-0.000122 (0.000394)	0.000110 (0.000549)	0.000174 (0.000574)
(1)	$\hat{\alpha}_2$	-0.349042 *** (0.033218)	-0.364968 *** (0.029537)	-0.356322 *** (0.032888)	-0.350310 *** (0.033395)
(1)	$\hat{\alpha}_3$	-0.006139 (0.005719)	-0.006793 (0.005783)	-0.005806 (0.005835)	-0.006314 (0.005931)
	Unexpected neutral announcement:	**Money Supply (*MS*)**	**Reserve Money (*RM*)**	**Balance of Payments (*BOP*)**	**Liquid Assets and Liabilities (*AL*)**
(1)	$\hat{\alpha}_4$ **neutral**	-0.287168 (0.176758)	0.353058 (0.291704)	-0.125883 (0.153337)	-0.078623 (0.139917)
	Conditional variance equation:				
(2)	$\hat{\beta}_0$	0.058185 * (0.031343)	0.081461 ** (0.036284)	0.039026 *** (0.014667)	0.056889 * (0.032007)
(2)	$\hat{\beta}_1$	0.096015 *** (0.032520)	0.153834 *** (0.042113)	0.093464 *** (0.035056)	0.097086 *** (0.032530)
(2)	$\hat{\beta}_2$	0.720549 *** (0.101241)	0.596688 *** (0.140290)	0.762828 *** (0.059198)	0.721408 *** (0.102682)
(2)	$\hat{\beta}_3$	0.001048 (0.001172)	-0.000045 (0.000395)	0.001090 (0.000982)	0.001081 (0.001169)
	Unexpected neutral announcement:	**Money Supply (*MS*)**	**Reserve Money (*RM*)**	**Balance of Payments (*BOP*)**	**Liquid Assets and Liabilities (*AL*)**
(2)	$\hat{\beta}_4$ **neutral**	-0.078741 (0.086525)	0.614543 (0.759319)	0.160164 (0.116310)	-0.003527 (0.098089)
		Q(10) = 5.0837 (p = 0.749) LM(10) = 0.205133 (p = 0.9959) Log likelihood = -701.4597	Q(10) = 7.0237 (p = 0.723) LM(10) = 0.819042 (p = 0.6103) Log likelihood = -689.0731	Q(10) = 6.9106 (p = 0.734) LM(10) = 0.182681 (p = 0.9975) Log likelihood = -701.8570	Q(10) = 7.2129 (p = 0.705) LM(10) = 0.179976 (p = 0.9976) Log likelihood = -703.8746

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Table 5 (continued):

Eq.	On day *t+1*				
	Mean equation:				
(1)	$\hat{\alpha}_0$	0.046264 (0.055898)	0.056777 (0.054884)	0.043313 (0.058514)	0.044698 (0.056206)
(1)	$\hat{\alpha}_1$	0.000211 (0.000571)	-0.000048 (0.000423)	0.000148 (0.000579)	0.000197 (0.000564)
(1)	$\hat{\alpha}_2$	-0.349661 *** (0.034155)	-0.350220 *** (0.029782)	-0.349209 *** (0.033276)	-0.347290 *** (0.033677)
(1)	$\hat{\alpha}_3$	-0.005873 (0.005904)	-0.006965 (0.005803)	-0.005355 (0.006193)	-0.006069 (0.005929)
	Unexpected neutral announcement:	**Money Supply (*MS*)**	**Reserve Money (*RM*)**	**Balance of Payments (*BOP*)**	**Liquid Assets and Liabilities (*AL*)**
(1)	$\hat{\alpha}_4$ **neutral**	0.048540 (0.115406)	-0.103836 (0.261657)	0.119645 (0.075787)	0.094787 (0.083164)
	Conditional variance equation:				
(2)	$\hat{\beta}_0$	0.064739 ** (0.031650)	0.073840 *** (0.023694)	0.054482 * (0.028796)	0.058070 ** (0.027025)
(2)	$\hat{\beta}_1$	0.098119 *** (0.032404)	0.134368 *** (0.031903)	0.100299 *** (0.033060)	0.087175 *** (0.033313)
(2)	$\hat{\beta}_2$	0.704085 *** (0.100760)	0.632697 *** (0.084391)	0.722541 *** (0.097171)	0.736156 *** (0.086483)
(2)	$\hat{\beta}_3$	0.000994 (0.001198)	0.000063 (0.000446)	0.001112 (0.001181)	0.000950 (0.001143)
	Unexpected neutral announcement:	**Money Supply (*MS*)**	**Reserve Money (*RM*)**	**Balance of Payments (*BOP*)**	**Liquid Assets and Liabilities (*AL*)**
(2)	$\hat{\beta}_4$ **neutral**	-0.138276 (0.090229)	0.706345 (0.759784)	0.022700 (0.083481)	-0.088031 (0.086955)
		Q(10) = 7.0750 (p = 0.718) LM(10) = 0.193930 (p = 0.9967) Log likelihood = -702.6370	Q(10) = 6.8118 (p = 0.743) LM(10) = 0.559981 (p = 0.8470) Log likelihood = -692.4169	Q(10) = 3.7777 (p = 0.151) LM(10) = 0.166860 (p = 0.9983) Log likelihood = -691.2455	Q(10) = 7.2915 (p = 0.698) LM(10) = 0.200073 (p = 0.9963) Log likelihood = -702.3592

Notes: Values of the standard errors in the brackets. The value of the Q(10) test for autocorrelation, the LM(10) test for any remaining ARCH effects and the log likelihood are reported in the bottom rows of every panel. Number of equation in the first column indicates whether the estimated parameters relate to the variables in the mean equation or in the conditional variance equation of the GARCH model.

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

Table 6. Results for volume of trade (percentage change) models with neutral announcements on days *t* and *t+1*.

This table reports estimates of dummy variables for the NBP announcements days with unexpected announcements of neutral strength in the mean equation (3):

$$\Delta Volume_t = \alpha_0 + \alpha_1 \cdot r_{t-1}^{PLN/USD} + \alpha_2 \cdot \sqrt{h_t^{PLN/USD}} + \alpha_3 \cdot DUM_{s,t} + \xi_t$$

and in the conditional variance equation (4):

$$h_t^{volume} = \beta_0 + \beta_1 \cdot \xi_{t-1}^2 + \beta_2 \cdot h_{t-1} + \beta_3 \cdot r_{t-1}^{PLN/USD} + \beta_4 \cdot DUM_{p,t}$$

from the GARCH model (3) - (4) of the PLN/USD volume of trade percentage changes.

Eq.	**On day *t***				
	Mean equation:				
(1)	$\hat{\alpha}_0$	22.63635 *** (5.116730)	21.28128 *** (5.159187)	19.52152 *** (4.984344)	20.36733 *** (5.308093)
(1)	$\hat{\alpha}_1$	4.484679 ** (1.993656)	4.261968 ** (2.105823)	3.875261 * (2.007690)	4.545232 ** (2.009472)
(1)	$\hat{\alpha}_2$	-19.18801 ** (7.786902)	-17.41104 ** (7.960861)	-15.06850 ** (7.564439)	-16.42068 ** (8.051352)
	Unexpected neutral announcement:	**Money Supply (*MS*)**	**Reserve Money (*RM*)**	**Balance of Payments (*BOP*)**	**Liquid Assets and Liabilities (*AL*)**
(1)	$\hat{\alpha}_3$ **neutral**	-12.53154 (14.16203)	20.40996 (15.71736)	16.99849 (11.39337)	13.61775 (9.550585)
	Conditional variance equation:				
(2)	$\hat{\beta}_0$	1554.748 *** (139.7946)	1550.520 *** (154.3894)	1554.791 *** (152.9996)	1548.335 *** (137.0525)
(2)	$\hat{\beta}_1$	0.257362 *** (0.088616)	0.220646 *** (0.073317)	0.245278 *** (0.090298)	0.258671 *** (0.089360)
(2)	$\hat{\beta}_2$	-	-	-	-
(2)	$\hat{\beta}_3$	337.2047 (219.9873)	119.9359 (239.8221)	230.5174 (217.1178)	382.9294 * (213.8856)
	Unexpected neutral announcement:	**Money Supply (*MS*)**	**Reserve Money (*RM*)**	**Balance of Payments (*BOP*)**	**Liquid Assets and Liabilities (*AL*)**
(2)	$\hat{\beta}_4$ **neutral**	5.973375 (905.8555)	4588.815 (3017.137)	1347.582 (1068.948)	1059.963 (893.7047)
		Q(10) = 6.3379 (p = 0.386) LM(10) = 0.764196 (p = 0.6636) Log likelihood = -4119.953	Q(10) = 8.1936 (p = 0.224) LM(10) = 0.592274 (p = 0.8211) Log likelihood = -4139.980	Q(10) = 9.1050 (p = 0.168) LM(10) = 0.436654 (p = 0.9288) Log likelihood = -4140.501	Q(10) = 6.5372 (p = 0.366) LM(10) = 0.737094 (p = 0.6897) Log likelihood = -4117.472

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Table 6 (continued):

Eq.	On day *t+1*				
	Mean equation:				
(1)	$\hat{\alpha}_0$	21.29179 *** (6.040690)	22.26559 *** (5.131231)	22.21483 *** (5.336497)	21.19361 *** (5.305919)
(1)	$\hat{\alpha}_1$	4.782643 ** (2.205141)	4.189596 ** (1.990373)	4.493162 ** (1.990006)	3.695622 * (2.095554)
(1)	$\hat{\alpha}_2$	-16.70217 * (9.144487)	-18.84081 ** (7.828287)	-18.85251 ** (8.047027)	-17.20854 ** (8.101267)
	Unexpected neutral announcement:	**Money Supply (MS)**	**Reserve Money (RM)**	**Balance of Payments (BOP)**	**Liquid Assets and Liabilities (AL)**
(1)	$\hat{\alpha}_3$ **neutral**	-6.188430 (13.43845)	-1.404994 (14.29200)	-2.617179 (10.48435)	-0.741541 (8.626078)
	Conditional variance equation:				
(2)	$\hat{\beta}_0$	1727.246 *** (151.5399)	1548.682 *** (140.2855)	1580.810 *** (140.5052)	1508.483 *** (155.7600)
(2)	$\hat{\beta}_1$	0.263972 *** (0.092377)	0.257703 *** (0.089625)	0.244539 *** (0.086900)	0.266998 *** (0.097361)
(2)	$\hat{\beta}_2$	-	-	-	-
(2)	$\hat{\beta}_3$	466.2667 ** (209.0081)	337.9121 (221.2204)	294.6604 (224.0570)	182.7685 (229.7529)
	Unexpected neutral announcement:	**Money Supply (MS)**	**Reserve Money (RM)**	**Balance of Payments (BOP)**	**Liquid Assets and Liabilities (AL)**
(2)	$\hat{\beta}_4$ **neutral**	-573.4625 (394.5352)	261.4724 (894.1275)	-690.1705 (446.1722)	-436.3571 (433.6345)
		Q(10) = 6.4406 (p = 0.169) LM(10) = 0.995802 (p = 0.4453) Log likelihood = -4114.964	Q(10) = 6.2265 (p = 0.398) LM(10) = 0.778105 (p = 0.6501) Log likelihood = -4114.448	Q(10) = 5.9336 (p = 0.431) LM(10) = 0.760927 (p = 0.6668) Log likelihood = -4113.783	Q(10) = 6.5275 (p = 0.367) LM(10) = 0.503199 (p = 0.8884) Log likelihood = -4109.541

Notes: Values of the standard errors in the brackets. The value of the Q(10) test for autocorrelation, the LM(10) test for any remaining ARCH effects and the log likelihood are reported in the bottom rows of every panel. Number of equation in the first column indicates whether the estimated parameters relate to the variables in the mean equation or in the conditional variance equation of the GARCH model.

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

Table 7. Performance of investment strategies for trades on day *t* (Panel A) and on day *t+1* (Panel B).

A. Results for dummies on day *t*:

Trading horizon from the NBP announcement at 4:00 PM CET:	**Time (CET):**	**Profit / loss (in bps) for different levels of transaction costs (in bps):**			
		0	*10*	*25*	*50*
+1 hour	5:00 PM	49	17	-31	-112
+3 hour	7:00 PM	109	76	28	-53
until the end of day t	various times PM	42	9	-39	-120
+16 hours	9:00 AM	45	22	-11	-67
+20 hours	12:00 AM	-224	-246	-280	-336
+24 hours	4:00 PM	-157	-179	-213	-268
until the end of day t+1	various times PM	-157	-179	-213	-268

B. Results for dummies on day *t+1*:

Trading horizon from the beginning of day *t+1*:	**Time (CET):**	**Profit / loss (in bps) for different levels of transaction costs (in bps):**			
		0	*10*	*25*	*50*
until 10:00 AM	10:00 AM	807	741	642	477
10:00 AM +3h	1:00 PM	1695	1629	1530	1365
10:00 AM +6h	4:00 PM	739	673	574	409
10:00 AM +9h	7:00 PM	653	587	488	323
until the end of day *t+1*	various times PM	653	587	488	323

Average for all trading horizons for days *t* and *t+1*:	**354.50**	**311.42**	**246.92**	**139.42**

Table 8. Breakdown of statistically significant estimation results for NBP announcement dummies of different strengths.

		Number of statistically significant estimates for dummies at the level of:			
		1%	**5%**	**10%**	**Sum:**
strongly positive	**for *t***	5	2	0	**7**
positive		4	1	3	**8**
negative		2	0	1	**3**
strongly negative		9	0	0	**9**
		1%	**5%**	**10%**	**Sum:**
strongly positive	**for *t+1***	3	1	0	**4**
positive		4	0	0	**4**
negative		1	1	2	**4**
strongly negative		10	0	0	**10**
		1%	**5%**	**10%**	**Sum:**
strongly positive and strongly negative	**for *t* and *t+1***	27	3	0	**30**
positive and negative		11	2	6	**19**

Note: The breakdown is based on the estimation results from all Tables 3a, 3b, 4a and 4b.

Figure 1. Returns of the PLN/USD exchange rate ($r_t^{PLN/USD}$), daily data (August 2000 – September 2003).

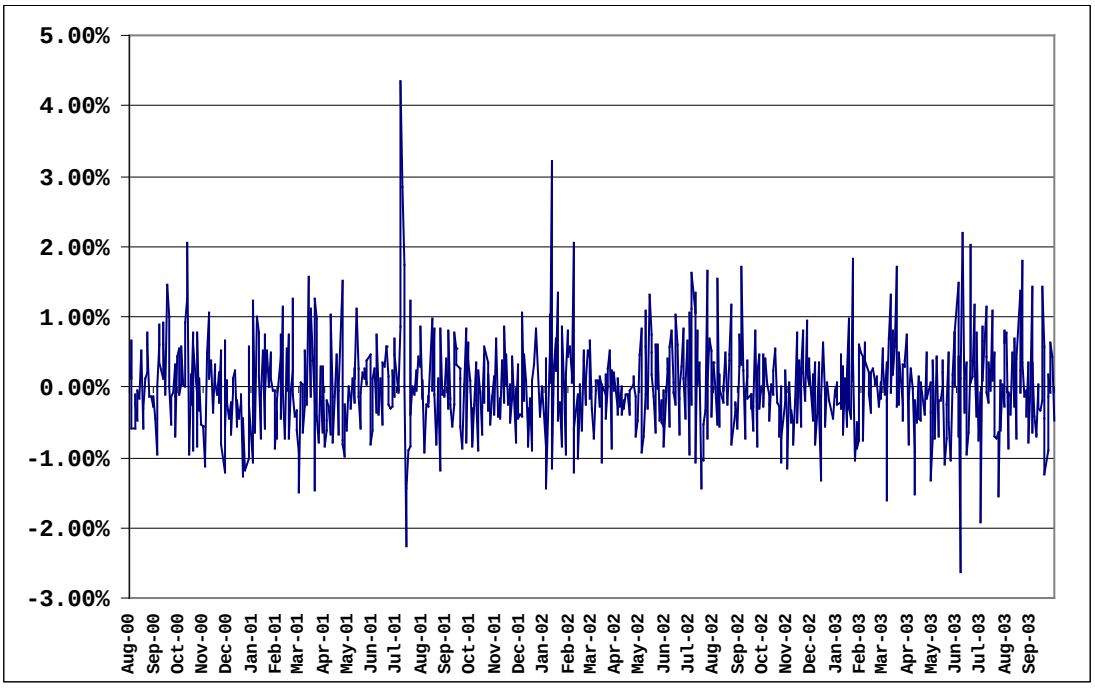

Figure 2. Returns of the EUR/USD exchange rate ($r_t^{EUR/USD}$), daily data (August 2000 – September 2003).

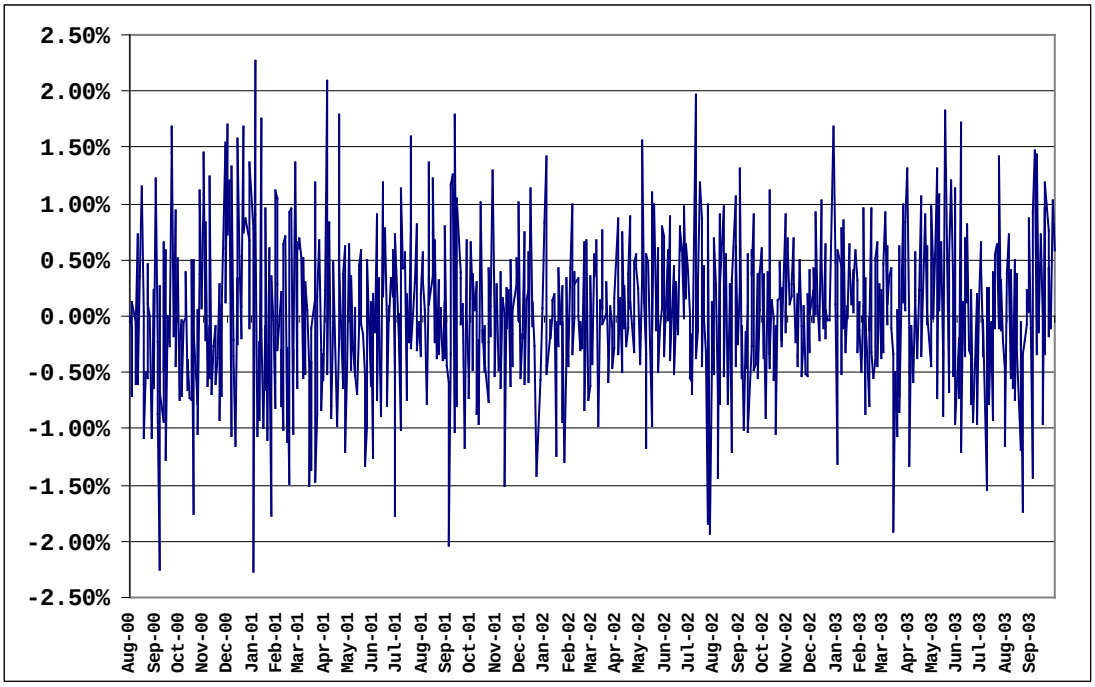

Figure 3. Levels of the PLN/USD and EUR/USD exchange rates, daily data (August 2000 – September 2003).

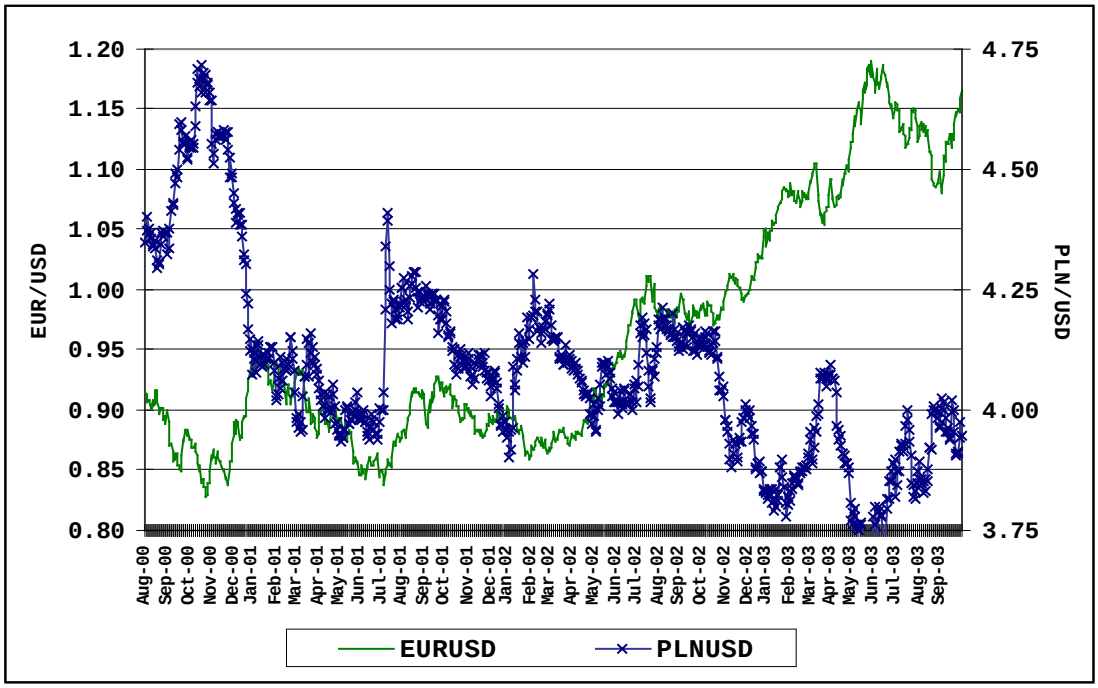

Figure 4. Interest rates and interest rates differentials between Poland and USA (FOMC fed funds rate and NBP Stopa Referencyjna), daily data (August 2000 – September 2003).

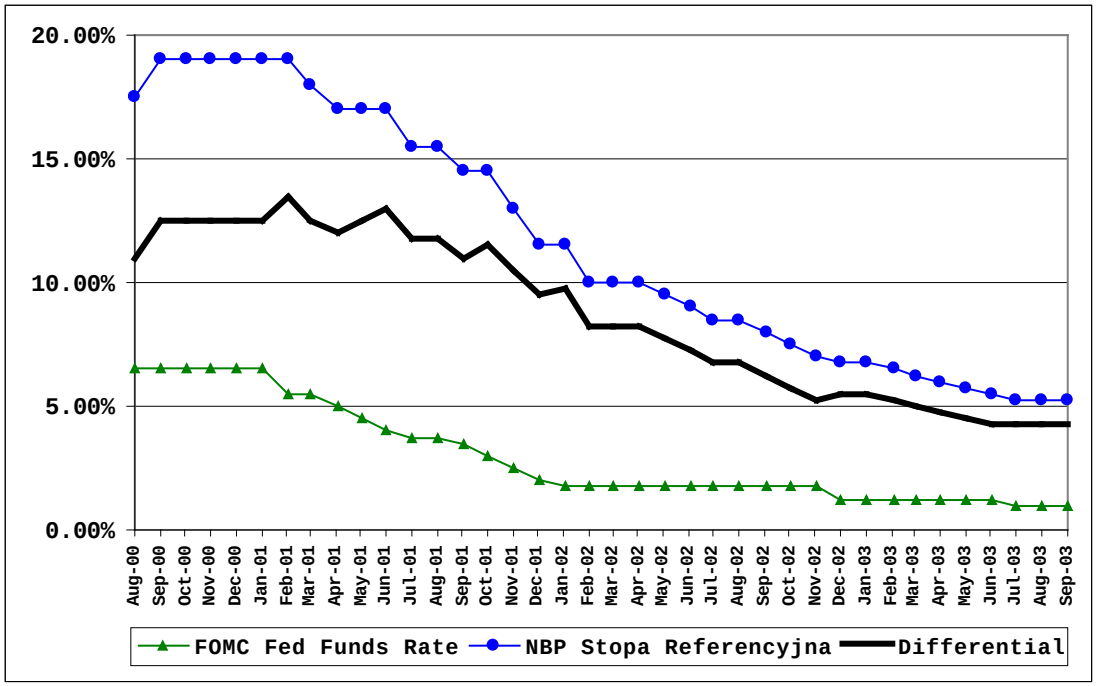

Figure 5. Percentage changes of the PLN/USD volume of trade ($\Delta Volume_t$), daily data (August 2000 – September 2003).

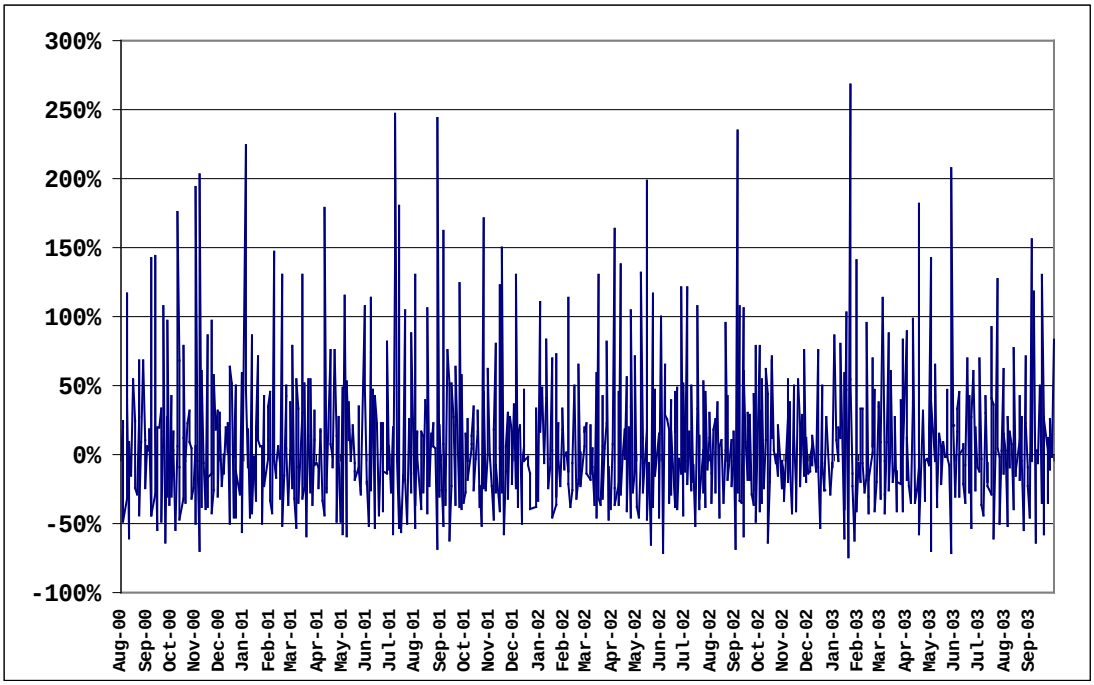

Figure 6. Unexpected announcements as proportion of the deviation from their moving average in their standard deviation (August 2000 – September 2003).