The problem of endogeneity in the identification of monetary surprises with Russian high-frequency data

Viktoriia Bannikova[†]

[†]*Lomonosov Moscow State University*

This paper addresses a question on the extent of endogeneity problem in the identification of monetary surprises with Russian high-frequency data. We propose an econometric framework to compare various approaches employed in Russian research field and find considerable evidence for the presence of an information component in the existing estimates of monetary surprises. As a byproduct of the research, we construct an extensive database of Russian monetary surprises which represent replications from different research papers, and we also develop an approach to estimate instant effects of monetary policy. We assess impact of monetary and information shocks on short-term and long-term interest rates and show that information shocks drive the yield curve distorting the results of event-study analysis.

Keywords: Russian monetary surprises, yield curve, information shocks

Introduction

A growing literature studies monetary policy and central bank communications using high-frequency approach. Recent research has found that standard estimates of monetary surprises are distorted by information component It allows a researcher to evaluate effects of the central bank (hereinafter referred to as, CB) communication policy.

In the case of Russian high-frequency data the problem of endogeneity is extremely urgent. Press-releases of the Bank of Russia convey information on the key rate changes as well as on the predicted macroeconomic situation and expected monetary policy path. At the same time, intra-daily data is available only for currency futures while data on the financial instruments which pay interest rates is accessible at daily frequency. This research paper raises a question on the extent of endogeneity in various cases of using high-frequency data. We estimate monetary surprises with the methods reported in the Russian economic literature and deconstruct them into pure monetary and information shocks. Then we obtain the estimates of the shocks impact on the yield curve and conclude on the role of information shocks in the event-study framework.

The contribution of the paper is twofold.

First, we address a question whether daily data or financial variables based on currency expectations is sufficient for identification of monetary policy shocks. In this regard our paper complements research Gürkaynak et al. (2007) who study a similar subject for the U.S. high-frequency data: they show that in 1994, since the FOMC began to announce the target rate, forming of expectations had changed, market participants became to adjust their expectations for monetary policy in the near future. Unlike the seminal paper, we compile a database for Russian high-frequency data and focus on differences between series of monetary surprises which stem from variations in data characteristics (frequency, liquidity, type of financial instruments). For this purpose, we develop a novel approach to compare the role of information component for different series of monetary surprises.

Second, we estimate the impact of monetary policy surprises on the yield curve. In contrast with most existing works, we interpret estimate of surprises as market reactions to the CB announcements: key rate policy can be a trigger in the forming of market expectations on future monetary policy and macroeconomic outlook, regardless of the CB communications content. Then we identify an information (endogenous) component and assess monetary shocks in view of the endogeneity problem. Finally, we adopt a heteroskedasticity-based method of Bu et al (2021) to get consistent estimates of monetary policy impact on the yield curve and simultaneously check the validity of assumptions, including an exogeneity assumption for estimates of the key rate and path shocks if possible. In contrast to Bu et al (2021), we model two dimensions of monetary policy – changes in the key rate and policy path, using the method only to assess monetary policy effects, not shocks. We do not find arguments for plausibility of the model assumptions. Possibly, CB information policy to some degree does play an important role in the emerging of market surprises and should be considered as a possible cause of endogeneity in the standard estimation of monetary surprises.

One of the main empirical findings is that the endogeneity problem is crucial for estimates of monetary surprises on Russian financial data. We show that stock prices co-move in half of cases, estimate information shock and demonstrate that it drives different ends of the yield curve in the opposite directions. However, high-frequency approach remains a state-of-the-art method in the monetary policy research not only for the U.S. and euro area but also for economies with financial markets such as Russian one. We find that financial variables based on interest rate expectations provide estimates of monetary surprises which are highly correlated with analytics' forecasts[1]. Moreover, sign restrictions proposed by Jarociński and Karadi (2020)

[1] This result is not new (see, Evstigneeva et al, 2022), however, it is not evident which measure is better for a particular study as we are not able to use intra-daily interest rate futures or swaps.

tend to be useful in the identification of Russian monetary surprises. We find that using implied inflation and stock exchange index lead to the same conclusions which we interpret by the endogeneity problem related to the standard measures of monetary surprises.

The remainder of this paper is structured as follows. In Section I we make a brief review on the related literature and determine blank spaces in the Russian research field. Section II describes the data on estimates of monetary surprises with the Russian high-frequency data. Section III reviews the econometric framework for the identification of monetary surprises and shows the estimates. Section IV introduces a method to assess effects of monetary policy on the yield curve and reports the results. Section V concludes.

Review of related literature

Dealing with the endogeneity problem in the high-frequency approach has become one of the common questions in the recent research on the identification of monetary policy shocks. The standard approach developed by Kuttner (2001) highlights the importance of unexpectedness in the assessment of shocks and suggests using futures data to extract unanticipated change in the monetary policy. Cieslak and Schrimpf (2019), Jarociński and Karadi (2020), Andrade and Ferroni (2021) demonstrate that estimation of unexpected variation in policy can be challenging due to the relevance of CB communication. The key result of these research papers is that information shocks distorting the inference are not just a noisy uninterpretable component, but also do have different effects on macroeconomic and financial variables.

The short 30-minute window around the CB announcements captures information about monetary policy and central bank's assessment of the economic outlook as well. Regarding this fact it biases the measurement of shocks and monetary non-neutrality. Jarociński and Karadi (2020) manage to extract an information component from monetary surprises which leads to consequences resembling demand shock effects. Cieslak and Schrimpf (2019) address the problem of information content of monetary surprises and find that 2 types of non-monetary news are present in standard Kuttner's surprises. The role of economic growth and risk premium news tends to be time-varying and crucial as the non-monetary news along with monetary shocks determine the dynamic of financial assets. Andrade and Ferroni (2021) modify the approach presented by Gürkaynak et al (2005) to consider different types of the ECB communication policy. The role of information asymmetry between the CB and the public and other channels in the emergence of monetary surprises is somehow out of the focus but represents a promising area for the future research (see, for example, Hoesch et al, 2023).

Daily window around the CB announcements is not widely employed in the case of liquid financial markets where minute bars on interest rate swaps and other instruments are available to researchers. However, using daily data is an appropriate alternative in some cases (Gürkaynak et al, 2007) and, moreover, can be advantageous for methods employing day-to-day observations of financial variables (Inoue, Rossi, 2019). Meanwhile, intra-daily data could require preprocessing procedures (Altavilla et al, 2019) as it does not have continuous coverage and does not always reflect actual market activity. The deficiencies of high-frequency approach prompted researchers to propose novel techniques for monetary shock identification (Bu et al, 2021). Cesa-Bianchi et al (2020) suggest a test of overidentifying restrictions to check that monetary policy surprises are not substantially affected by non-monetary news. However, the exogeneity of estimates severely depends on a specification used to identify shocks which had earlier motivated research to develop multi-dimensional factor models (Stock, Watson, 2002; Bernanke et al, 2005). Bu et al (2021) use a more flexible method of two-step least squares with valid instrumental variables.

In order to assess unexpected changes in monetary policy, Russian research papers employ high-frequency data with different characteristics (frequency, liquidity, interest rate and other financial instruments). For instance, Tishin (2019) use intraday currency futures, Evstigneeva et al (2022) estimate surprises with daily interest swaps and government bonds, Abramov et al (2022) gain access to an extended set of various financial instruments. Russian intraday data is relatively scarce[2] and is related to financial instruments which are not based on interest rates. However, calculating Kuttner's surprises on prices of, for example, currency futures and stock exchange index tend to be ambiguous since modelling suggests assumptions on permanent links between expected interest rates and expectations on other variables. The considered short window around the CB announcements does not ensure implementation of these relationships at each moment of time (i.e., at each announcement). To some degree, the current empirics contradicts the data-driven essence of the high-frequency approach where a standard Kuttner's monetary surprise is a time-varying market assessment of monetary policy shocks.

Identification of the information component on Russian data represents a novel area in the research field. In the foreign literature researchers often use the co-movement of interest rates and stock prices (or break-even inflation rates) assuming that the present value of future dividends raises or declines due to 1) corresponding changes in the discount rate and 2) improving or deteriorating outlook caused by monetary surprise (Cieslak and Schrimpf, 2019; Jarociński and Karadi, 2020; Andrade and Ferroni, 2021). However, the widely spread approach of sign restrictions needs to be empirically tested and well-founded before interpretation. In case of Russia, the need for additional restrictions is a priori unknown. Nevertheless, exogeneity of monetary surprises estimates obtained on Russian financial data is commonly assumed (e.g., «the week of silence») and is rarely investigated empirically[3], while it is essential for unbiased and consistent estimates.

[2] This fact applies primarily to the liquid currency futures on the USD/RUB, the data on which is available, at most, 3-months before the expiration (the data for assessing 1-week or 1-month interest rates is very scarce).
[3] See Kramkov, Maksimov (2023) for details. They estimate pure monetary policy shock on *daily* data only and do not address the problem of policy *multidimensionality*.

Preliminary analysis of the data

In this Section we replicate high-frequency estimates from several Russian research papers. We derive several series of Russian monetary surprises by computing changes in prices of different financial assets in the windows around the CB announcements (press-releases and press-conferences of the Bank of Russia). In constructing the database, we take 3 types of windows: 1) a daily window around the press-release and the press-conference which happen on the same day of the meeting, 2) 30-minute window around the press-release, 3) 30-minute windows around the press-release and the press-conference if the latter occurs.

In order «to minimize the risk of selecting a quote that is not representative» in the last 2 cases, we follow Altavilla et al (2019) and apply a median approach to use intervals instead of separate quotes as bounds of the window. Particularly, we use the median price in the 13:10–13:20 interval as the pre-press-release quote and the median price in the 13:45–13:55 interval as the post-press-release quote (see, Figure 1). In the similar way, we make use of intervals for press-conferences and for that we record the actual runtime of press-conferences[4]. The dates and the start time of the press-releases and press-conferences are scrapped from the official website of the Bank of Russia[5].

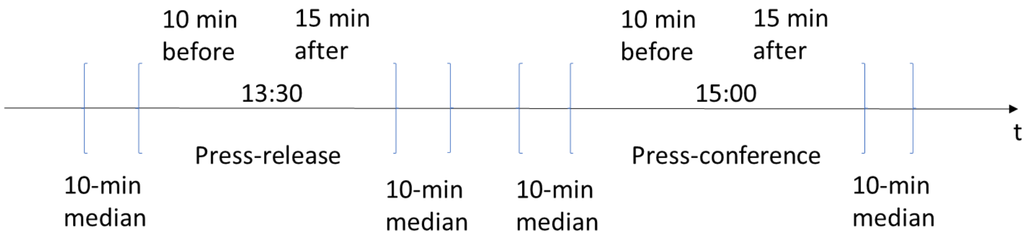


Figure 1. The timeline of the press-releases and press-conferences for the Bank of Russia

In our work we follow the periodization of Russian monetary policy proposed by Pestova (2017). Our sample consists of the dates of all monetary events from January 2010 through April 2023, although for some dates the data for financial instruments is not available due to the suspension of investing and trading (for example, March and April 2022). During the period since 2009 the monetary policy of the Bank of Russia is characterized as interest rate policy.

[4] Videos of the press-conferences are located on the official website of the Bank of Russia and are also available on the YouTube channel: https://www.youtube.com/playlist?list=PLQocLHHmkYbCsWDJphENzmIqMcrcU-SxD

[5] The main source: http://www.cbr.ru/dkp/cal_mp/. The dates and timestamps for the earlier CB decisions (2010–2014) were collected from the old version of the same website during the work under previous research (Bannikova, Pestova, 2021).

First, we follow Evstigneeva et al (2022) and calculate daily changes in the ROISfix indicative rate with terms of 1 week, of 2, 3, and 6 months, and changes in the index of federal loan bonds (OFZ) with terms of 1, 2 and 5 years.

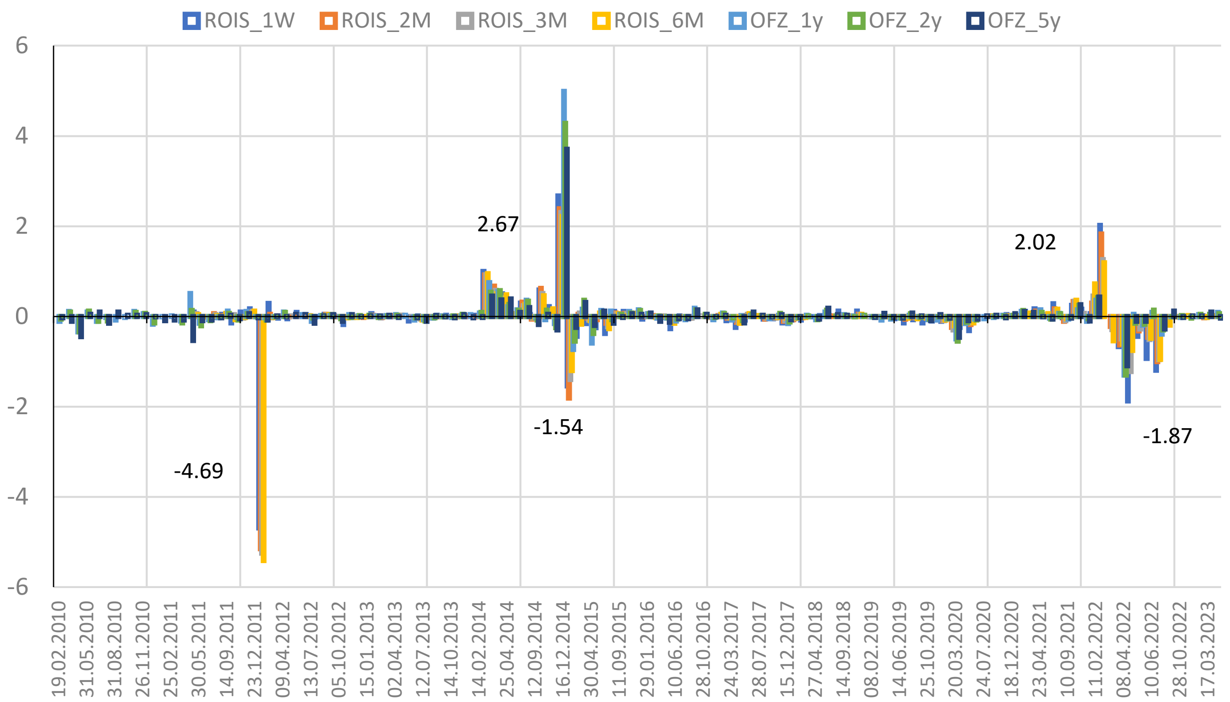


Figure 2. Daily monetary surprises estimated with 1-week, 2-month, 3-month, 6-month ROISfix surprises and 1-year, 2-year, 5-year OFZ surprises. Data labels are related to 1-week ROISfix index.

Further, we denote this approach by the first letters of the research authors – ESS'22. We denote the series as $MPS_t^{ROIS\_X}$ and $MPS_t^{OFZ\_X}$ relatively, where X is a term for indices and t denotes the closest to the CB meeting day when the CB announcement precedes the moment of publishing interest rate index[6]:

$$MPS_t^{ROIS\_X} = ROIS\_X_t - ROIS\_X_{t-1} \quad (1)$$

$$MPS_t^{OFZ\_X} = OFZ\_X_t - OFZ\_X_{t-1} \quad (2)$$

Figure 2 displays the described series of monetary surprises. The largest surprises for 1-week ROISfix index are observed for the following CB meetings: 3 February 2012, 16 December 2014, 30 January 2015, 11 February 2022, 29 April 2022. Two of them are positive and reflect two unexpected hikes of the key rate when the Bank of Russia decided to raise the CB rate from 10.5 to 17.00 percent and from 8.50 to 9.50 percent per annum in the conditions high inflation and economic uncertainty. The surprises for the rest of the dates also stem from the

[6] See details in Evstigneeva et al (2022).

CB decisions: in 2012 the CB remain the interest rate unchanged, and the inflation rate hit a record low of 3,7% annum by the end of February, in the beginning of 2015 and in April 2022 the CB started to reduce the key rate after the two unpreceded hikes.

We also get measures of the so-called news through the same formulas (1) and (2) just for the day before t:

$$MPS_{t-1}^{ROIS\_X} = ROIS\_X_{t-1} - ROIS\_X_{t-2} \quad (3)$$

$$MPS_{t-1}^{OFZ\_X} = OFZ\_X_{t-1} - OFZ\_X_{t-2} \quad (4)$$

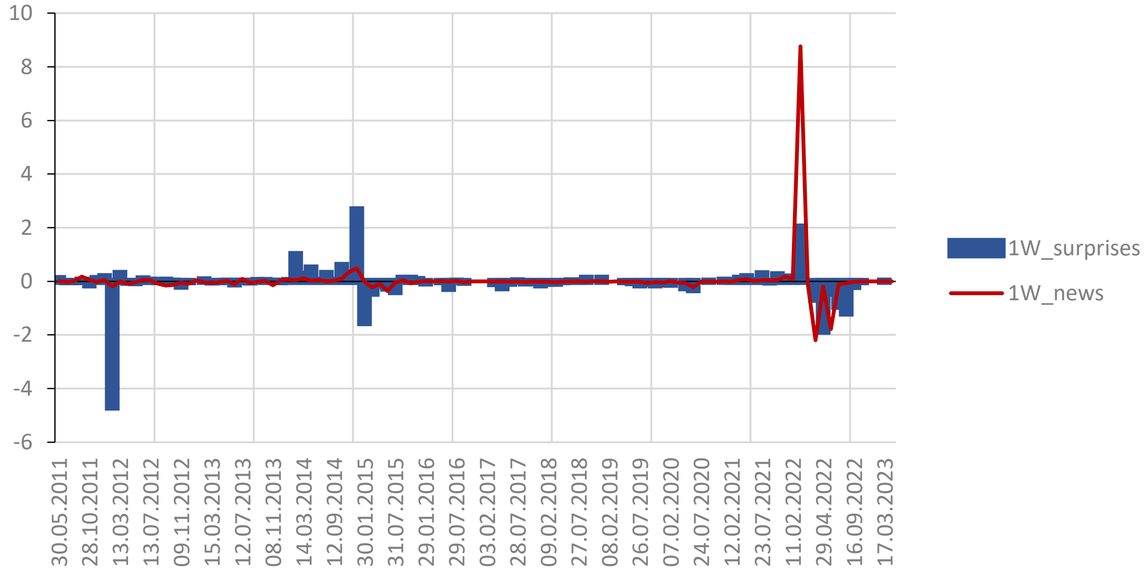


Figure 3. Daily monetary surprises and news estimated with 1-week ROISfix surprises

Figure 3 displays our measures of news and surprises for ROISfix 1-week index. It shows, the investors at most guess the direction of monetary policy stance and expect a key rate hike or fall as needed but make uncorrected predictions of the value of the key rate change (the same sign in 84,5% of cases). The correlation between the two measures of news and surprises for 1-week ROISfix is not strong ($R^2 = 0.15$ with outliers and $R^2 = 0.14$ without outliers). The values of statistical variance for them are 0.01 and 0.29, respectively (without outliers mentioned above).

To illustrate the assumption on «the week of silence» we also calculate monetary policy surprises in the wider windows around the CB announcements (2-day, 3-day and 4-day windows) for the use in the further two sections. Figure 4 depicts these series and the original series of monetary policy surprises estimated with 1-week ROISfix index in a cumulative way. The wider the window is, the more sound the change of the interest rate index is. During the week of silence investors possibly tend to form their expectations on the key rate and partly anticipate an actual change in monetary policy, however, the surprise takes place at the day of the CB meeting.

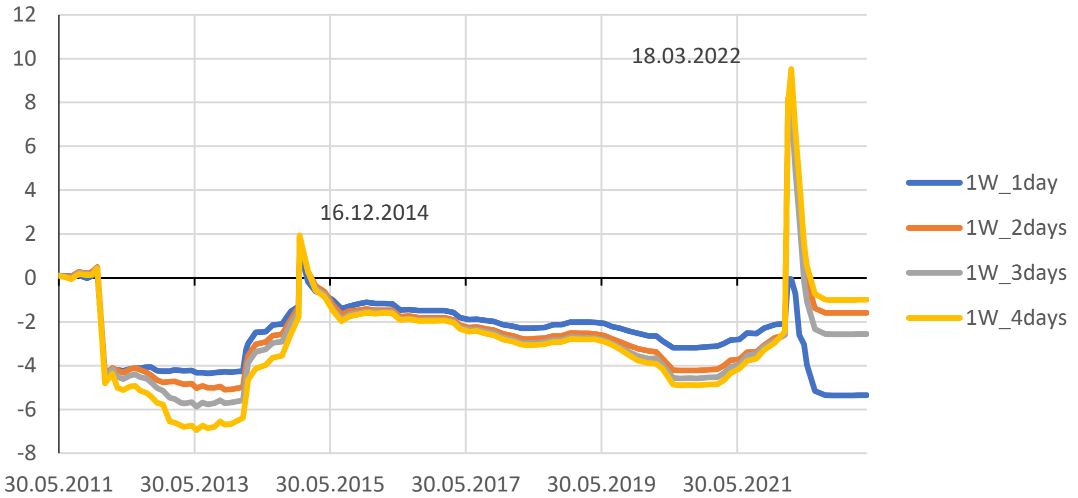


Figure 4. The cumulative values of daily monetary surprises in the 1-day, 2-day, 3-day and 4-day windows around the CB meeting days estimated with 1-week ROISfix surprises

Second, we use daily and intraday data on currency futures with different expiration terms 3, 6, 9 and 12 months and spot exchange rate (Tishin, 2019; Berestova, 2020). Figure 5 displays the series of monetary surprises (further – Tishin’19/ Berestova’20).

Figure 5. Daily monetary surprises estimated with 3-month, 6-month, 9-month and 12-month currency futures and spot exchange rate (daily Tishin’19/ Berestova’20)

Third, we also apply the uncovered interest rate parity (UIP) to the same time series of currency instruments, in order to estimate new measures of monetary surprises like Bannikova, Pestova (2021) do but for a larger number of variables – currency futures with different expiration terms up to 360 days (further – BP’21):

$$\left(\frac{E_{t,\tau+20}[S_{t+T}]}{S_{t,\tau+20}} - \frac{E_{t,\tau-10}[S_{t+T}]}{S_{t,\tau-10}}\right) \cdot \frac{365}{T} = i^{RUB}_{t,\tau+20} - i^{RUB}_{t,\tau-10}, \tag{5}$$

where S_t – inverse spot rate of the national currency, $E_t[S_{t+T}]$ – the expected futures exchange rate of the national currency in T days since t, i_{RUB} – ruble interest rate, r_{USD} – dollar interest rate, T – a number of days before the expiration of the futures contract.

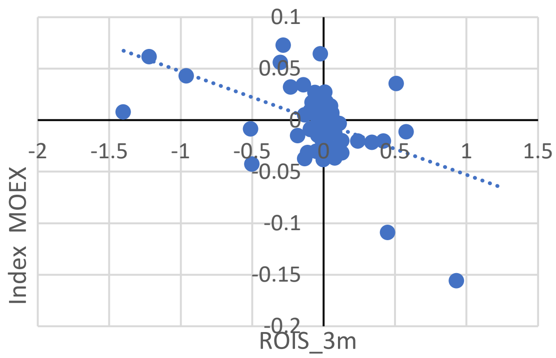
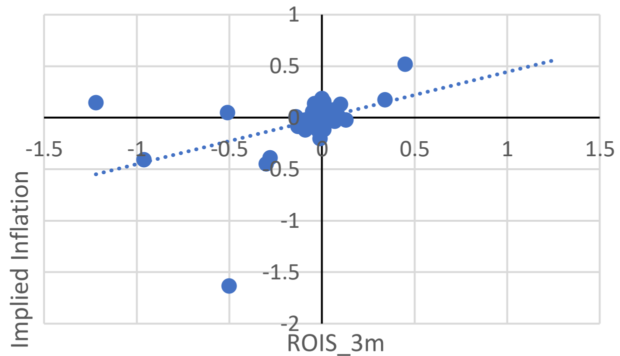
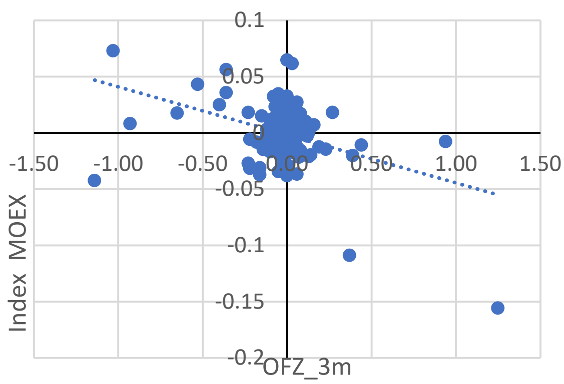
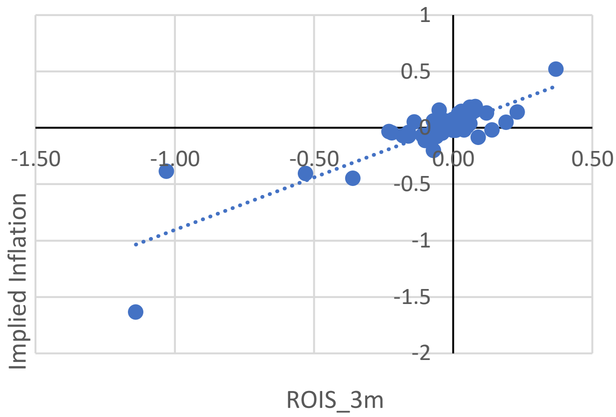
Correlation with the MOEX index	**Correlation with implied inflation**
a) ROISfix with a term of 3 months	a) ROISfix with a term of 3 months
	
b) OFZ with a term of 3 months	b) OFZ with a term of 3 months
	

Figure 6. Scatterplots of the 3-month interest rate surprises and changes of the MOEX index (left) or implied inflation (right)

In conclusion, we end the preliminary analysis of the data with discussion of the co-movement between the different estimates of monetary policy surprises and changes of the stock prices and implied inflation in the relevant window around the CB decision. For this purpose, we use the MOEX index, and the measure of inflation expectations proposed in the Methodological commentary of the Bank of Russia (Andreev, Orlov, 2021). The Figure 6 displays the scatter plots for the interest rate surprises and changes of the MOEX index (see the left-side panel), and the implied inflation (see the right-side panel). Following Jarociński and Karadi (2020), we use changes in the 3-month implied interest rates which incorporate expectations about actual rate setting and near-term CB signals on policy path and macroeconomic outlook.

The stock prices and interest rates (ROISfix and OFZ) co-move in 32.5 and 49.6 per cent of cases, relatively. If we take inflation expectations, we get the proportion value 53.4 and 69.0%, accordingly[7]. Approximately, in half of the cases signs of the stock prices and inflation expectations coincides. This empirical fact does not tell against the presence of information shocks as they could be simultaneous along with monetary shocks. Furthermore, one of the possible problems is that inflation expectations react in the wider window than one-day interval. This can be explained, in particular, with the method used for the series construction: the measure of breakeven inflation is contaminated by risk and term premia. However, we also use changes in the implied inflation as an alternative to the stock price index.

We also compare various series of monetary surprises such as analysts' expectations and estimates based on daily data of 1-week ROISfix index, 3-month OFZ index, USD/RUB currency futures and intra-daily data for currency futures in the windows of the press-releases and press-conferences. Interest rate variables provide estimates which are consistent with analysts' expectations to a larger extent. Further, we prefer them to identify monetary policy shocks and study the question of the information shock's role using different data.

[7] The number of observations for implied inflation is less, than in the case the stock price index as data on the inflation-linked bonds begin since October 2015.

Information content of monetary surprises

We exploit a method of the structural VAR with monotonicity and sign restrictions to analyze the information content of the Bank of Russia announcements. This approach is closely related to the paper of Cieslak, Schrimpf (2019) except the set of restrictions imposed on the elements of the impact matrix. We suppose that 3 structural shocks $\varepsilon_t = \{\varepsilon_t^{(1)}, \varepsilon_t^{(2)}, \varepsilon_t^{(3)}\}$ affect high-frequency estimates of monetary surprises – changes in the interest rates at different maturities (3-month and 6-month) derived from different financial instruments and stock prices (MOEX index). Generally, we denote them as $u_t = \{\Delta i_t^{sr}, \Delta i_t^{lr}, \Delta stocks_t\}$.

The choice of maturities is motivated by the fact that we have access to daily and intraday data on the 3-month, 6-month, 9-month and 12-month currency futures, the first two of which are preferable due to liquidity issues. Moreover, 3- and 6-month interest rate indices like ROISfix and OFZ are accessible. In the framework of definite identification scheme, we estimate shocks and historical decompositions to assess the contribution of each shock to monetary surprises estimated with the help of the data with different characteristics (daily vs. intra-daily, currency futures vs. interest rate index).

However, 3-month and 6-month interest rates are quite similar, and 3 months is not the shortest term which is interesting for monetary policy (an operating target of the Bank of Russia is 1-day interbank interest rate). During the period of 2010-2022 the number of the CB meetings varied between 2–4 times in 3 months. Then 3-month interest rate surprises capture the effects of near-term forward-guidance[8]. Further, we impose sign and monotonicity restrictions instead of zero one to take into account different terms of interest rates.

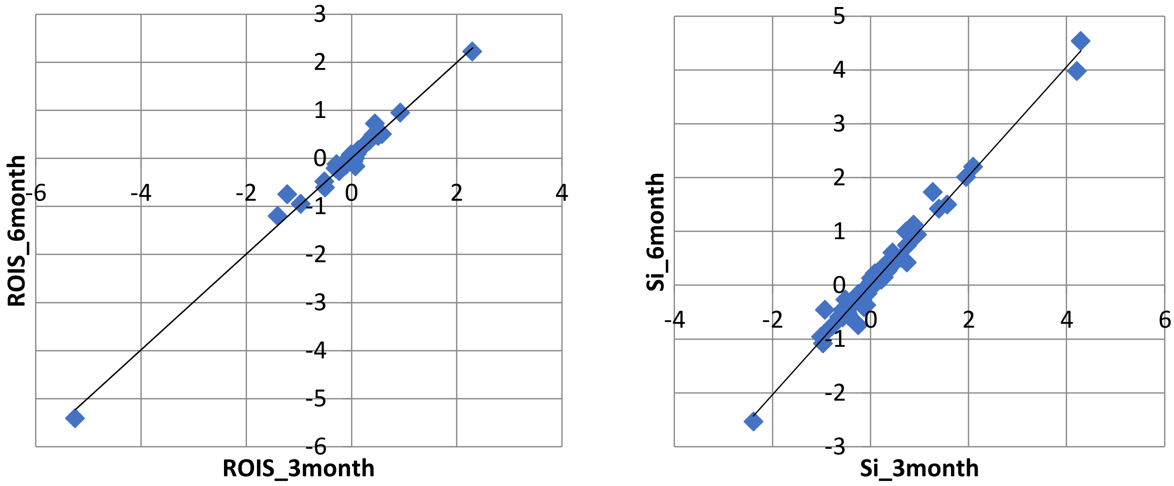
Following Gürkaynak et al. (2007) to some degree, we compare two shocks of measures (3-month and 6-month ones) in the scatterplot (see, Figure 7). For the daily data the series of changes in the implied 3-month and 6-month interest rates are highly correlated and are lying along the line at 45 degrees to the axes. This is not the case only for few dates. The same picture (unreported) is for a pair of variables (ROISfix indices) with terms 1 week and 3 or 6 months. However, for intra-daily surprises in the window of press-release and press-conference the shocks differ considerably. We interpret these differences as effects of the CB signaling which can be short-term or useful in the identification information policy effects.

Now, we consider a question about the role of information (or endogenous) component. An increase in the interest rates can be explained by monetary policy action or endogenous

[8] The Bank of Russia carry out traditional interest rate monetary policy. We use the expression "near-term forward-guidance" for the CB signals and forecasts.

reaction to it. In the first case market participants adjust their expectations for inflation or future returns along with the logic of monetary policy transmission. In the latter one - investors correct their expectations due to an error in the predicting value of the key rate (for example, unexpected tightening is associated with mispricing inflation risk and leads to an increase in expected inflation). Therefore, we estimate a model with corresponding sign restrictions for changes in interest rates and stock prices or implied inflation.

A.



B.

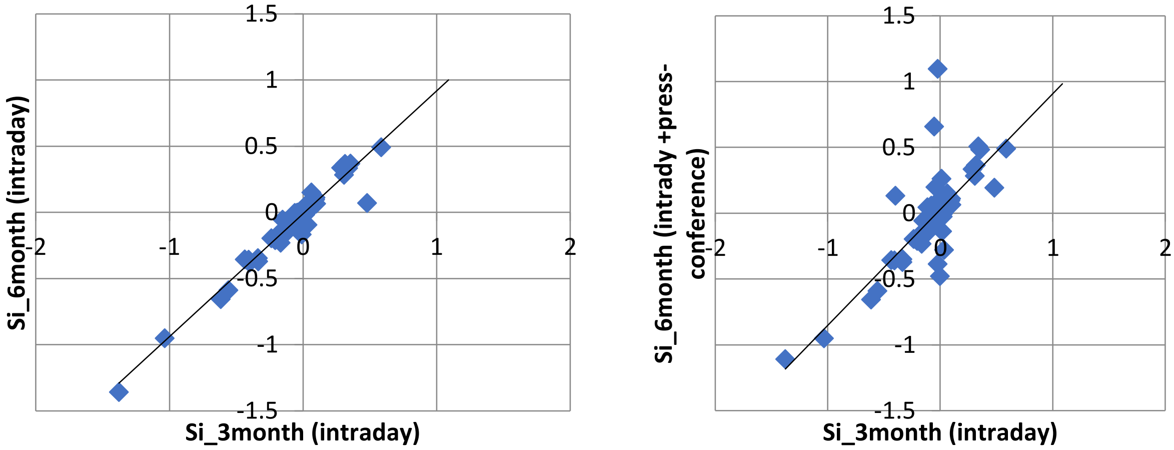


Figure 7. Comparison of two measures of monetary surprises (Panel A: left – daily ROISfix changes, right – daily currency futures; Panel B: intra-daily currency futures, left – press-release window, right – press-release + press-conference window). Notes: Using a wider window (only or jointly) for 3-month currency futures transform a line scatter plot to a diffused point cloud.

The reduced-form shocks u_t connected to structural shocks ε_t through an impact matrix A:

$$u_t = A^{-1}\varepsilon_t,$$

where structural shocks ε_t have a zero mean and a diagonal identity variance-covariance matrix. Sign restrictions on the elements of the matrix A^{-1} are the following:

$$A^{-1} = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} = \begin{pmatrix} + & + & + \\ + & + & + \\ - & - & + \end{pmatrix},$$

where the first two structural shocks $\varepsilon_t^{(1)}, \varepsilon_t^{(2)}$ and the third shock $\varepsilon_t^{(3)}$ have a positive impact on the interest rates but are characterized by different effects on the stock price changes (negative and positive, respectively). The latter idea stems from Jarociński and Karadi (2020): we identify an information shock when an interest rate hike is accompanied by a stock price increase. However, it can be uninterpretable and reflects variations due to random noise. By contrast, we do not follow an interpretation proposed by Jarociński and Karadi (2020) calling the endogenous component «a central bank information shock»[9]. We suppose that the market participants might update their expectations on the state of the economy not just in the presence of the central bank information advantage (Morris, Shin, 2002).

To differentiate the first two shocks, we impose monotonicity restrictions:

$$|a_{11}| > |a_{12}|, \tag{1}$$

$$|a_{21}| < |a_{22}|, \tag{2}$$

$$|a_{11}| > |a_{21}|, \tag{3}$$

$$|a_{12}| < |a_{22}| \tag{4}$$

The restrictions (1) and (3) capture that $\varepsilon_t^{(1)}$ affects short-term interest rates more than interest rates with a longer maturity and $\varepsilon_t^{(1)}$ affects short-term interest rates more than $\varepsilon_t^{(2)}$. In detail, $\varepsilon_t^{(1)}$ represents a shock affecting the spot rate. As a central bank regulates the short end of the yield curve $\varepsilon_t^{(1)}$ is associated with the shock of the key rate. Similarly, the restrictions (2) and (4) let us interpret $\varepsilon_t^{(2)}$ as a path shock affecting forward interest rates. Interest rates with longer maturity respond more to the shock $\varepsilon_t^{(2)}$ than interest rates with shorter maturity and respond stronger to the shock $\varepsilon_t^{(2)}$ than to the other shock $\varepsilon_t^{(1)}$. The penultimate restriction is proposed to be included since many research papers find an information shock during the period of interest rate monetary policy of the Bank of Russia. Further, we will call them «key rate shock», «path shock», «information shock».

---

[9] Evstigneeva et al (2022) make a conclusion on the predominant role of the central bank information advantage in the emergence of Russian monetary surprises. However, we leave this topic for future research after distinguishing information and monetary components.

The last restriction is ambiguous as it is proposed that path shock is strong enough to drive longer-term interest rates. For that reason, we modify the base specification in the following ways. First, the assumption (2) is omitted. Second, within the used algorithm we impose so-called «zero restrictions» when a_{12} is less than 0.01 by the absolute value and has an undetermined sign. We call the types of described identification schemes «Identification I» and «Identification II».

In the Table 1 we report results of the variance decomposition for different specifications. It shows that a more flexible identification (Type I) coincides with the fact that a path shock almost does not contribute to a short-term interest rate like 1-week ROISfix or 3-month OFZ index, although, we do not have such a restriction. It is also correct for baseline identification when a term discrepancy is large enough (for example, for 3-month and 3-year[10] OFZ indices) which does not depend on the type of identification. This empirical fact is an argument in favor of «multidimensionality» of monetary surprises (i.e., changes in the key rate and policy path).

Comparing the results for intraday and daily data we find that for all specifications the contribution of path shocks to interest rates is larger when we prefer higher frequencies. Adding information of the press-conference window seems to be favorable while comparing decompositions for intra-daily data.

For the Identification I (the most flexible one from 3 schemes presented) daily ROISfix indices and daily currency futures data provide just the same results. However, using ROISfix and OFZ data does not lead to similar decompositions. We attribute this to the liquidity of government bonds when investors do not manage to react in response to the CB information (Abramov et al, 2022) or when other macroeconomic news appears which can affect the yield curve (changes in the neutral interest rate, risk premia).

Type of identification	Variables	Key rate shock	Path shock	Information shock
Baseline	OFZ_3m OFZ_6m IMOEX_daily	**0.37** 0.21 0.34	0.21 **0.38** 0.36	**0.42** **0.42** 0.30
	OFZ_3m OFZ_3y IMOEX_daily	**0.61** 0.11 0.33	0.09 **0.66** 0.39	**0.30** 0.23 0.28
	ROIS_1w ROIS_6m IMOEX_daily	**0.52** 0.14 0.28	0.11 **0.53** 0.31	0.37 0.33 **0.41**
	ROIS_3m	**0.38**	0.19	0.43

[10] The choice of 3-year term is rational as 3 years is the Bank of Russia forecasting.

	ROIS_6m	0.16	**0.36**	**0.47**
	IMOEX_daily	**0.38**	0.29	0.33
	Si_daily_3m	**0.38**	0.17	0.45
	Si_daily_6m	0.14	**0.34**	**0.52**
	IMOEX_daily	0.33	0.25	0.41
	Si_intraday_3m	**0.59**	0.08	0.33
	Si_intraday_6m	0.12	**0.63**	0.25
	IMOEX_intraday	0.25	0.31	**0.44**
	Si_intraday_3m	**0.58**	0.08	0.34
	Si_intraday_6m	0.11	**0.65**	0.24
	IMOEX _intraday (+press-conference)	0.26	0.29	**0.46**
Identification I	OFZ_3m	**0.58**	0.11	0.31
	OFZ_6m	0.40	0.24	**0.36**
	IMOEX_daily	0.28	**0.41**	0.30
	OFZ_3m	**0.63**	0.08	**0.29**
	OFZ_3y	0.12	**0.64**	0.24
	IMOEX_daily	0.32	0.40	0.28
	ROIS_1w	**0.58**	0.09	0.33
	ROIS_6m	0.18	**0.49**	0.33
	IMOEX_daily	0.25	0.35	**0.40**
	ROIS_3m	**0.57**	0.11	0.32
	ROIS_6m	0.34	0.25	**0.41**
	IMOEX_daily	0.29	**0.35**	0.36
	Si_daily_3m	**0.56**	0.11	0.34
	Si_daily_6m	0.30	0.24	**0.46**
	IMOEX_daily	0.24	**0.30**	0.45
	Si_intraday_3m	**0.54**	0.09	0.37
	Si_intraday_6m	0.21	**0.43**	0.36
	IMOEX_intraday	0.23	0.34	**0.43**
	Si_intraday_3m	**0.46**	0.11	**0.43**
	Si_intraday_6m	0.14	**0.48**	0.38
	IMOEX _intraday (+press-conference)	0.27	0.30	0.42
Identification II	OFZ_3m	**0.66**	0.00	0.34
	OFZ_6m	0.53	0.05	**0.41**
	IMOEX_daily	0.39	**0.38**	0.23
	OFZ_3m	**0.67**	0.00	**0.33**
	OFZ_3y	0.21	**0.47**	0.32
	IMOEX_daily	0.40	0.38	0.22
	ROIS_1w	**0.61**	0.00	0.39
	ROIS_6m	0.30	0.25	**0.45**
	IMOEX_daily	0.30	**0.43**	0.27
	ROIS_3m	**0.63**	0.00	0.37
	ROIS_6m	0.43	0.06	**0.51**
	IMOEX_daily	0.36	**0.40**	0.24
	Si_daily_3m	**0.58**	0.00	0.42
	Si_daily_6m	0.37	0.05	**0.58**
	IMOEX_daily	0.33	**0.37**	0.30

	Si_intraday_3m Si_intraday_6m IMOEX_intraday	**0.59** 0.34 0.27	0.00 0.19 **0.46**	0.41 **0.47** 0.27
	Si_intraday_3m Si_intraday_6m IMOEX _intraday (+press-conference)	**0.62** 0.23 0.27	0.00 0.39 **0.43**	**0.38** **0.38** 0.30

Table 1. Variance decompositions of government bond yield (or the other ones) and stock index changes around the announcements of the Bank of Russia. Before estimations the outliers were excluded from the sample: for example, 29/04/2011, 03/03/2014, 16/12/2014, 30/01/2015, 08/04/2022 and 26/05/2022 for OFZ indices. The maximum values are indicated in bold print.

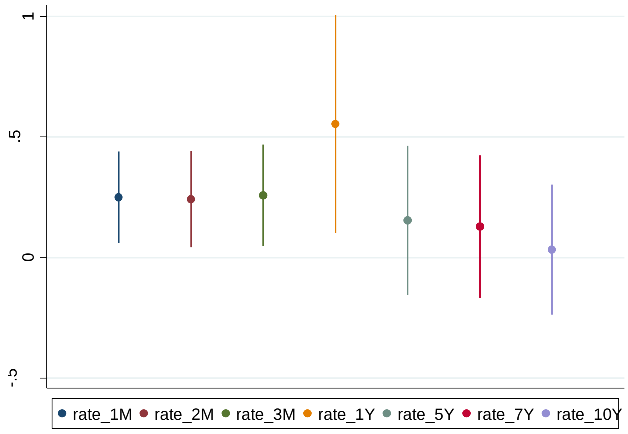
Contribution of the information component to interest rate surprises ranges from 24 to 58 per cent in different specifications. The results of variance decompositions lead to the conclusion that the information component role might be not so crucial for empirics.

We also apply historical decompositions to quantify how important one of the identified shocks is in explaining the behavior of endogenous variables in each period of the years of the Bank of Russia's interest rate policy. Consequent estimation of the base specification on the different datasets allows us to compare the series of high-frequency data and conclude on the role of information shocks for each approach to estimate monetary surprises. The role of information shocks is positive, enhancing during 2010-2016/2017, and then they influence interest rates negatively.

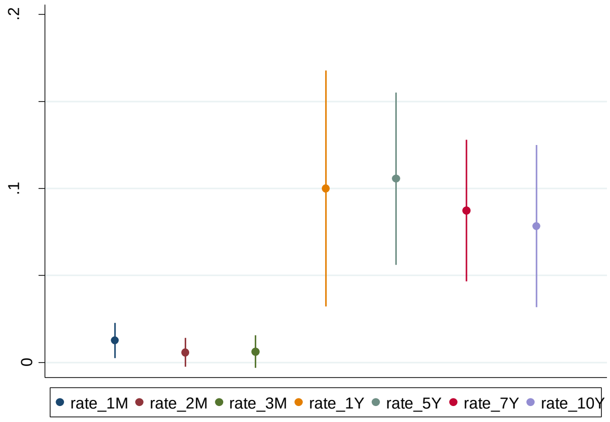
Evstigneeva et al (2022) demonstrate that during 2015-2022 a target factor is predominantly associated with negative unexpected changes in the key rate and a path factor is co-moved with a target factor which is consistent with the monetary policy implemented by the Bank of Russia. Our historical decompositions are in line with this fact: since 2015 path and key rate shocks mainly co-move.

To check conclusions on press-conference information and other facts associated with different characteristics of the intraday data, we also estimate shocks for the baseline specification with intraday data and estimate effects on the yield curve. Figure 8 displays the estimates of instant effects of monetary policy on the yield curve.

A:



B:



C:

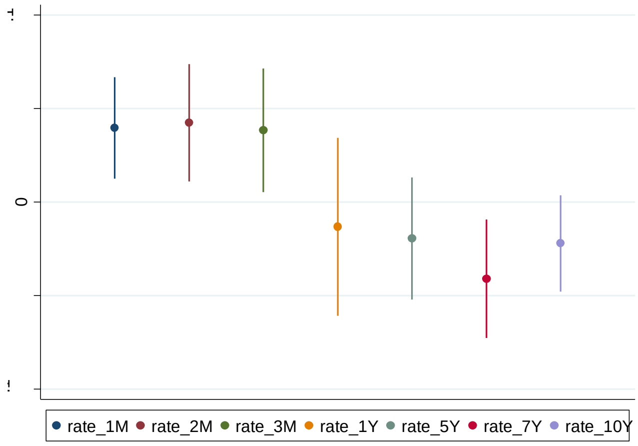


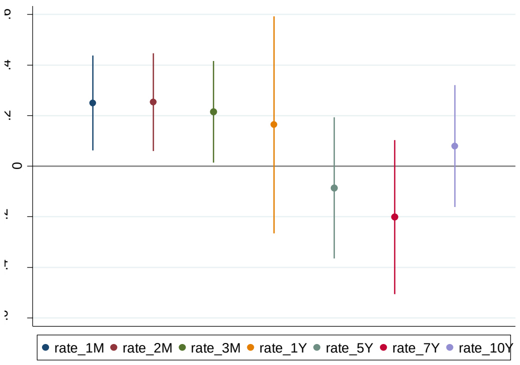
Figure 8. The estimates of the coefficients in the regressions of government bond yields on the key rate, path and information shocks. The coefficient values and their confidence intervals (86%) are plotted for the variable A) «key rate shock», B) «path shock», C) «information shock».

We find that futures contracts with 3 and 6 months before the expiration have substantially different volumes of trade. However, we compare the values for 6-month USD/RUB and 3-month EUR/RUB futures (Figure 9). The next step is to use these contracts to calculate monetary surprises in the windows around press-releases and press-conferences of the Bank of Russia. Reaction of the yield curve to monetary shocks become monotonous (Figure 10). We cannot be sure that a real reason is liquidity, one of possible reasons is almost similar maturities.

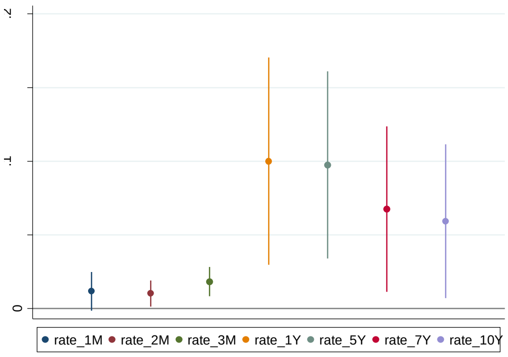
Дата	Si-12.22 Число сделок	Si-12.22 Объем торгов		Eu-9.22 Число сделок	Eu-9.22 Объем торгов	
		руб.	контр.		руб.	контр.
01.06.2022	3 425	1 700 284 946	25 409	2 626	427 466 155	6 374
02.06.2022	1 299	233 895 944	3 467	2 394	423 617 468	6 222
03.06.2022	2 943	473 258 222	6 988	3 508	486 492 622	7 079
06.06.2022	2 205	419 933 308	6 256	2 158	334 024 806	4 931
07.06.2022	1 983	343 612 452	5 126	2 224	283 104 445	4 182
08.06.2022	3 907	788 280 323	11 881	4 003	704 777 089	10 489
09.06.2022	5 552	878 909 261	13 587	6 091	1 003 120 471	15 264
10.06.2022	6 057	1 025 918 629	16 046	11 009	2 265 715 095	34 841
14.06.2022	10 995	3 080 444 663	48 207	7 038	1 577 362 770	24 828
15.06.2022	7 856	1 845 880 796	28 880	17 644	3 215 470 342	51 386

Figure 9. Liquidity indicators of futures contracts for currency pairs (dollar/ruble – more than 90 days before the expiration, euro/ruble – less than 90 days before the expiration) on a specific date in the first half of June 2022. Source: official website of the Moscow Exchange

A:



B:



C:

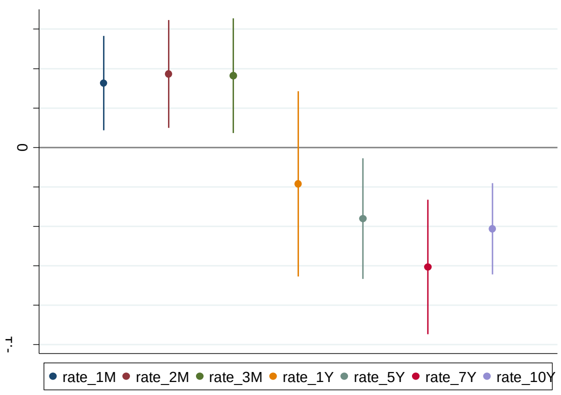


Figure 10. The estimates of the coefficients in the regressions of government bond yields on the key rate, path and information shocks. Currency futures: dollar/ruble and euro/ruble. The

coefficient values and their confidence intervals (86%) are plotted for the variable A) «key rate shock», B) «path shock», C) «information shock».

To test the robustness of information shock estimates, we use changes in the implied inflation instead of changes in the stock index. The series of expected inflation are less liquid compared to the stock index, it is also daily data (not intraday as for the stock index) and it is available only since July 2015. However, they allow to cross-check whether the expectation revision is connected to non-monetary information. Figure 11 illustrates the results of historical decompositions of intraday changes in the stock prices and daily changes in the implied inflation.

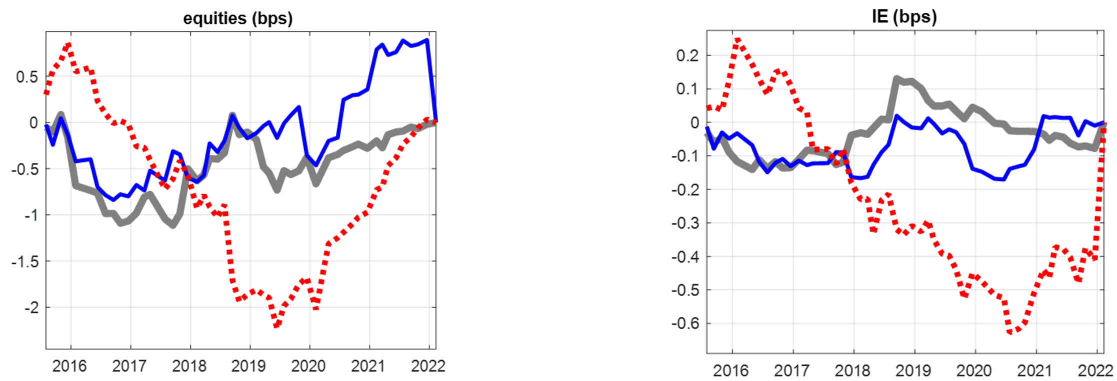


Figure 11. Historical decomposition of stock prices and implied inflation daily changes (grey – key rate shock, blue – path shock, red – information shock). Shocks are normalized to have zero mean and are cumulated over time. The type of the identification scheme is the baseline.

Figure 11 also illustrates the features of the expectations revision by market participants in the post-crisis period 2015-2017: in terms of the cut key rate investors revised their inflation expectations up along with the expected interest rate. This can be interpreted as follows: before the Central Bank's announcement investors underestimated inflation risks and after receiving new information from the CB market participants adjusted their expectations upwards.

In conclusion, we re-estimate the effects on the yield curve after widening the window around monetary events (press-release + press-conference). We take into account information of the press-conference window only for 6-month interest rates as we consider Q&A session as a main source for market expectation adjustments. Figure 12 depicts estimates of the coefficients in the regressions of government bond yields on the key rate, path and information shocks in comparison with the base specification.

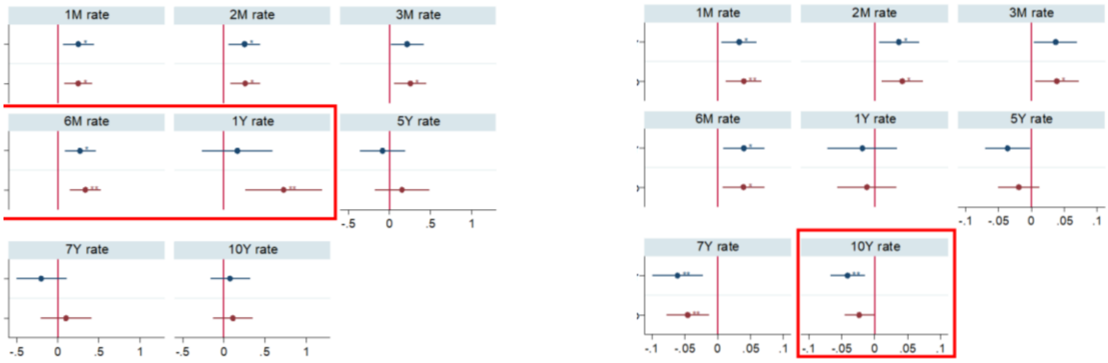


Figure 12. The estimates of the coefficients in the regressions of government bond yields on the key rate, path and information shocks (blue – short window, red – wide window). The coefficient values and their confidence intervals (86%) are plotted for the variable A) «key rate shock», B) «path shock», C) «information shock».

When we use the press-conference window for both series of interest rate surprises an impact of the key rate shock affects at most 1-year government bond yields. At the same time an impact of information shocks on the 10-year interest rate becomes statistically insignificant. We explain this result by the fact that the information from the press conference window is useful for identifying path and information shocks.

However, it is worth noting that the overall result is not strongly statistically significant (the significance level is greater than 10%) and robust to the change of the identification type as reaction of government bond yields to estimated shocks become non-monotonic if we switch between specifications.

Impact of the monetary surprise on the yield curve

To sum up, we slightly modify the approach Bu et al (2021) to get consistent estimates and show that we can expand their heteroskedasticity-based method to the case with 2 monetary policy shocks (See Table 2). So, we can use it to get consistent estimates of the effects of key rate and policy path shocks on the yield curve. The solution is equivalent to the 2SLS estimation, and one can check that proposed instruments satisfy the conditions of relevance and exogeneity.

	Method [Bu et al, 2021]	Proposed modification
Problem	$\Delta R_{1,t} = e_t + \eta_t$ $\Delta R_{n,t} = \beta_n e_t + \varepsilon_{n,t},$ $n \neq 1$ e_t – unobserved monetary shock	$\boldsymbol{Key_t} = e_t + \eta_t + \varepsilon_t^0$ $\boldsymbol{Path_t = a_t + \rho_1 \eta_t} + \varepsilon_t^1$ $\Delta R_{n,t} = \beta_n e_t + \boldsymbol{\gamma_n a_t + \rho_n \eta_t} + \varepsilon_t^n,$ $n \neq 1$ e_t, a_t – unobserved key rate and path shocks
Assumptions	1. $\sigma_e^M > \sigma_e^{NM}$ $\sigma_\eta^M = \sigma_\eta^{NM}$ $\sigma_\varepsilon^M = \sigma_\varepsilon^{NM}$ 2. $cov(e_t, \eta_t) = 0$ $cov(e_t, \varepsilon_{n,t}) = 0$ $cov(\eta_t, \varepsilon_{n,t}) = 0$	1. $\sigma_e^M > \sigma_e^{NM}$ $\sigma_\eta^M = \sigma_\eta^{NM}$ $\sigma_\varepsilon^M = \sigma_\varepsilon^{NM}$ $\boldsymbol{\sigma_a^M > \sigma_a^{NM}}$ 2. $cov(e_t, \eta_t) = 0$ $\boldsymbol{cov(e_t, a_t) = 0}$ $cov(e_t, \varepsilon_{n,t}) = 0$ $\boldsymbol{cov(a_t, \varepsilon_{n,t}) = 0}$ $cov(\eta_t, \varepsilon_{n,t}) = 0$ $\boldsymbol{cov(a_t, \eta_t) = 0}$ $\boldsymbol{cov(\varepsilon_{i,t}, \varepsilon_{j,t}) = 0, i \neq j}$
Regressions	$\Delta R_{n,t} = \beta_n Key_t + \xi_{n,t}$	$\Delta R_{n,t} = \beta_n Key_t + \boldsymbol{\gamma_n Path_t} + \xi_{n,t}$
Analytical solution for $\widehat{\beta_n}, \widehat{\gamma_n}$	$\widehat{\beta_n} = \frac{E[(\Delta R_{1t}^M, -\Delta R_{1t}^{NM})(\Delta R_{nt}^M, \Delta R_{nt}^{NM})']}{E[(\Delta R_{1t}^M, -\Delta R_{1t}^{NM})(\Delta R_{1t}^M, \Delta R_{1t}^{NM})']}$	$\widehat{\beta_n} = \frac{E[(Key_t^M, -Key_t^{NM})(\Delta R_{nt}^M, \Delta R_{nt}^{NM})']}{E[(Key_t^M, -Key_t^{NM})(Key_t^M, Key_t^{NM})']}$ $\widehat{\boldsymbol{\gamma_n}} = \frac{\boldsymbol{E\left[(Path_t^M, -Path_t^{NM})(\Delta R_{nt}^M, \Delta R_{nt}^{NM})'\right]}}{\boldsymbol{E\left[(Path_t^M, -Path_t^{NM})(Path_t^M, Path_t^{NM})'\right]}}$

Table 2. Comparison of the existing method and a proposed one

In the baseline specification we use daily and intra-daily estimates of monetary policy shocks replicated from ESS'2022 and Berestova'22. We also use our estimations of key rate and path shocks (Identification I, 3m-3y OFZ index). In the second case we apply 2 methods – ordinary least squares (OLS) and heteroskedasticity-based approach (HB). The last one provides unintuitive results[11] which means that the problem of endogeneity is not solved, or the setting is not correct (i.e., relationships between monetary and information shocks and yield curve tend to be different from proposed ones). However, OLS-estimation of the simple event-study regressions provide results clear to interpret. Significance of the coefficients coincides with the logic of «path» and «target» surprises. We can propose that sign restrictions are useful in the dealing with endogeneity problems on Russian data as well. All results are presented in Table 3.

Regressor / Dependent	ESS'22		Berestova'22		Our approach	
	Key_t	$Path_t$	Key_t	$Path_t$	Key_t	$Path_t$
$\Delta ROIS\_1w_t$	**1.44*****	0.002				
ΔOFZ_3m_t	0.059***	0.03	0.137**	0.12	**0.115*****	0.019*
ΔOFZ_6m_t	0.059***	0.034*	**0.139****	0.13*	0.097***	0.029***
ΔOFZ_9m_t	0.06***	**0.035***	0.129**	**0.125***	0.08***	0.04***
ΔOFZ_1y_t	0.058***	0.033*	0.113*	0.112*	0.066***	0.052***
ΔOFZ_2y_t	0.04***	0.021	0.07	0.087	0.033***	0.093***
ΔOFZ_3y_t	0.022	0.014	0.059	0.088	0.024***	**0.106*****
ΔOFZ_5y_t	0.001	0.009	0.044	0.086	0.023***	0.100***

Table 3. Regression analysis of government bond yields. The list of dependent variables is presented in the 1st column, the regressors include estimated factors/shocks. The robust standard errors are used. The maximum values are indicated in bold print. The level of significance: *** - 1%, ** - 5%, * - 10%.

The essential assumption in the heteroskedasticity-based approach is that the variance of the non-monetary (information) shock remains unchanged on the days of the CB meetings. However, this proposition seems to be implausible given the fact that investors can adjust their expectations on future policy and macroeconomic situation, regardless of how much and what information the CB disclose along with the monetary policy decision (Morris, Shin, 2002). Other assumptions on variances of the target and path shocks were tested in the previous research (Berestova, 2022; Kramkov, Maksimov, forthcoming). Partly, we can interpret our findings by the incorrect assumption.

[11] The yield curve reaction to monetary policy is not monotonous and it is challenging to interpret it.

Conclusion

This paper introduces an answer to the question on the presence of an endogeneity problem in the existing estimates of monetary surprises using Russian high-frequency data. We develop a novel econometric framework to compare different estimates of monetary and information shocks. We assess the contribution of the information component to interest rate surprises and find that it ranges from 24 to 58 per cent in different specifications and various data.

We show that stock prices co-move in the half of cases and apply sign restrictions proposed by Jarociński and Karadi (2020), which tends to be useful in the identification of monetary shocks. Our results demonstrate that the information shocks are crucial in the monetary shocks identification and drive different ends of the yield curve.

We demonstrate that the variance of equity returns and also inflation expectations around announcements is mostly driven by the information component of monetary surprises that apparently makes policy more unpredictable by market. On the background of inflation targeting adoption, in 2015-2016 investors expected an interest rate cut and at the same time revised up inflation expectations due to non-monetary information. In the latter period investors revised them down that may indicate a positive impact of the Central Bank's policy on the stabilization of inflation expectations.

Moreover, our results show that information of press-conference window can be useful for path shock identification and intra-daily data on currency futures is appropriate in the assessing information shocks. However, it tends to be challenging to extract the target shock from currency futures due to liquidity problems.

Our results reveal new areas for the research in the part of information effects and especially the reasons of emerging information component. In the current research there is lack of identification distinguishing between «Fed information effect» and «Fed response to news» channels of monetary policy. Furthermore, it is necessary to understand the underlying causal relationships between monetary and information policy and market reaction – which is triggered by the key rate changes or various aspects of the CB communication.

We conclude that high-frequency approach is the state-of-the-art in the monetary policy research not only for the U.S. and euro area but also for economies with financial markets such as the Russian case. However, it is a challenging work. We hope that future research on monetary surprise identification with Russian data will shed light on various aspects of high-frequency approach in the case of economies with forming financial markets.

References

1. Abramov, V., Styrin, K., & Tishin, A. (2022). Monetary Policy and the Yield Curve. *Bank of Russia working paper series, 95*.
2. Altavilla, C., Brugnolini, L., Gürkaynak, R. S., Motto, R., & Ragusa, G. (2019). Measuring euro area monetary policy. *Journal of Monetary Economics*, *108*, 162–179.
3. Andrade, P., & Ferroni, F. (2021). Delphic and odyssean monetary policy shocks: Evidence from the euro area. *Journal of Monetary Economics*, *117*, 816–832.
4. Bannikova, V. A., & Pestova, A. A. (2021). The effects of monetary shocks on inflation: High-frequency approach. *Voprosy Ekonomiki*, (6), 47–76.
5. Berestova, V. A. (2022). The impact of monetary policy transparency on the financial market. *Final qualifying work, Moscow State University*.
6. Bernanke, B. S., Boivin, J., & Eliasz, P. (2005). Measuring the effects of monetary policy: a factor-augmented vector autoregressive (FAVAR) approach. *The Quarterly journal of economics*, *120*(1), 387–422.
7. Cieslak, A., & Schrimpf, A. (2019). Non-monetary news in central bank communication. *Journal of International Economics*, *118*, 293–315.
8. Evstigneeva, A., Shchadilova, Y., & Sidorovskiy, M. (2022). The Role of Communication and Information Factors in the Emergence of Surprises in Bank of Russia Monetary Policy. *Bank of Russia working paper series, 99*.
9. Gürkaynak, R. S., Sack, B., & Swanson, E. T. (2005). Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements. *International Journal of Central Banking*, *1(1)*, 55–93.
10. Gürkaynak, R. S., Sack, B. P., & Swanson, E. T. (2007). Market-based measures of monetary policy expectations. *Journal of Business & Economic Statistics*, *25*(2), 201–212.
11. Hoesch, L., Rossi, B., & Sekhposyan, T. (2023). Has the Information Channel of Monetary Policy Disappeared? Revisiting the Empirical Evidence. *American Economic Journal: Macroeconomics*.
12. Inoue, A., & Rossi, B. (2019). The effects of conventional and unconventional monetary policy on exchange rates. *Journal of International Economics*, *118*, 419–447.
13. Jarociński, M., & Karadi, P. (2020). Deconstructing monetary policy surprises—the role of information shocks. *American Economic Journal: Macroeconomics*, *12*(2), 1–43.
14. Kramkov, V., & Maksimov, A. Monetary policy surprises and the yield curve in Russia. *Forthcoming*.

15. Kuttner, K. N. (2001). Monetary policy surprises and interest rates: Evidence from the Fed funds futures market. *Journal of monetary economics*, *47*(3), 523–544.
16. Morris, S., & Shin, H. S. (2002). Social value of public information. *The American Economic Review*, *92*(5), 1521–1521.
17. Pestova, A. (2017). Monetary policy regimes in Russia: Guidelines for further quantitative studies. *Voprosy Economiki*, *4*.
18. Stock, J. H., & Watson, M. W. (2002). Forecasting using principal components from a large number of predictors. *Journal of the American statistical association*, *97*(460), 1167–1179.
19. Tishin, A. (2019). Monetary policy surprises in Russia. *Russian Journal of Money and Finance*, *78*(4), 48–70.