Monetary Policy and the Yield Curve*

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Abstract

This paper discusses the impact of monetary policy on financial and macroeconomic variables in Russia. We distinguish two dimensions of monetary policy: (1) one caused by changes in the current rates; and (2) one caused by any other reason (such as forward guidance or communication or information from the central bank). We find that these two dimensions have distinct effects on financial variables. The first dimension better explains the variation of interest rates over the entire yield curve. In contrast, the second dimension is closely related to the variation in the exchange rate and market indices. Additionally, we also show that monetary policy transmission from interest rates to inflation takes about one year, but that this effect is only temporary.

Keywords: monetary policy surprises, high-frequency identification, principal component analysis

JEL Codes: E52, E58, E43, E44

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1 INTRODUCTION

Monetary policy remains the most important tool for achieving price stability, especially since many central banks have adopted the inflation targeting paradigm. Since many advanced economies (AEs) are stuck in liquidity traps, unconventional monetary policy has become commonplace and necessary. However, in emerging market economies (EMEs), interest rates are usually rather far above the zero lower bound, and inflation is much more volatile. Central banks in EMEs therefore more actively use their conventional policy tools (e.g., the policy rate) to manage inflation.

Furthermore, there is widespread agreement that monetary policy is not one-dimensional, and indeed, it has many aspects (Gürkaynak, Sack, and Swanson (2005), Altavilla et al. (2019), and Jarociński and Karadi (2020) and many others). For instance, according to the theory of interest rate expectations (Mishkin, 2007), a change in the monetary policy rate today influences not only today's short-term money market rates, but also expectations about the future interest rates in the economy. In addition, central banks try to manage expectations via various types of public communication by giving press conferences after policy meetings and by providing numerous analytical and research publications (e.g., disclosing the expected future path of the key rate, GDP growth trajectories, or explaining their understanding of the economic situation and the underlying risks in the economy). It is therefore important to correctly estimate how different dimensions of monetary policy are transmitted to the real economy and financial markets.

In this paper, we attempt to assess monetary policy transmission in Russia. To do so, we assume that monetary policy is multidimensional, namely, that it has two separate dimensions. The first, which we call 'regular monetary policy' (target shock), influences only short-term rates.[1] The second, which we call 'forward guidance' monetary policy (path shock), influences medium- and long-term rates.[2] Specifically,

[1]The near part of the yield curve.
[2]The further part of the yield curve.

we collect the exact dates and times of each policy meeting from 2011 onward and then calculate the daily return for each instrument for the day of each meeting. Then, we apply principal component analysis (PCA) to this set of daily monetary policy surprises to extract the first two components. Finally, we find a rotation of these components such that the first principal component corresponds with regular monetary policy and the second with forward guidance monetary policy.

The transmission of Russian monetary policy to the financial market has not yet been studied in depth. Tishin (2019) applies a high-frequency identification scheme to the Russian economy. Although he uses only one high-frequency instrument and identified only one monetary policy shock, he found a price puzzle. Other papers, such as the work of Pestova and Bannikova (2021), have undertaken further research of Russian monetary policy and improved the estimation of monetary policy surprises by exploiting uncovered interest rate parity. However, they still use a one-dimensional monetary policy measure and still observe a price puzzle.

We fill this gap and find that target and path shocks play conceptually different roles in the transmission of monetary policy. Target shock is more important to the term structure of interest rates. It increases the short-term rate at an almost 1:1 ratio. In addition, it also statistically significantly influences long-term rates. In response to a 25-basis point (bp) target shock, the 15-years bond yield increases by 10 bp, which is a bit larger than is usually found in similar exercises for the US and EA. However, the role of path shock in interest rates is considerably smaller. A 10-bp path shock influences only medium- and long-term interest rates, less than their original value (<10 basis points). Target shock explains almost all of the variance in interest rates.

Path shock is more important for financial variables. For example, in response to a 25-basis point target shock, the exchange rate appreciates by less than 1%, and the stock market index responds insignificantly. However, in response to a 10-basis point path shock, the exchange rate depreciates by more than 1%, and the stock market index decreases. Furthermore, path shock explains much variation in financial variables. Thus, unconventional policy, such as forward guidance, is not very impactful on short-term or long-term rates, but it has a potent impact on Russia's asset prices and exchange rate dynamics. Our results are robust for different specifications of monetary policy shock.[3] We additionally estimate our models on a rolling window subsample to ensure that our results are not caused by periods of high turbulence or structural breaks.

Our contribution is three-fold. First, we adapt the methodology of Gürkaynak, Sack, and Swanson (2005) to Russian data: we combine high-frequency data for exchange-traded and over-the-counter (OTC) instruments. Second, the multidimensionality of monetary policy is novel in the study of Russia and it solves the price puzzles that emerge from many previous papers. This area of inquiry is equally important for academic research and for the design and evaluation of monetary policy. Third, we apply our results to both financial and macroeconomic variables, while previous papers have usually studied them separately.

In this paper, we rely on high-frequency monetary policy surprises, pioneered by Kuttner (2001), which have gained tremendous popularity in modern literature. He was the first who disentangled the expected component of policy actions from unanticipated shocks using data from futures markets to estimate the transmission mechanism from monetary policy decisions to interest rates in the economy. The idea behind basic high-frequency identification (HFI) is to isolate a monetary policy shock within a tight-enough time window around the monetary policy decision (or other monetary policy communication event). By assumption, there is no other systematic news in this time window, except the monetary policy event itself. A substantial advantage of high-frequency data is that monetary policy shocks under the HFI approach usually bear less endogeneity bias than their VAR-based counterparts.

While high-frequency identification has become a standard tool in the study of monetary policy transmission, many early studies find puzzling effects from the use of one-dimensional measures of monetary policy. Later researchers, however, have significantly developed the idea of HFI. The role of information and other shocks

[3] Different instruments used to identify monetary policy shocks.

that emerge from monetary policy announcements is now widely acknowledged in the literature. There are seminal papers (such as those of Gürkaynak, Sack, and Swanson (2005), Jarociński and Karadi (2020), Jarocinski (2021), and Swanson (2021)) that provide evidence that policy announcements involve a mix of different monetary policy shocks — current rate decisions, large-scale asset purchases, disclosure of private central bank information, forecasts about the future state of the economy, and so on.

The idea of the multidimensionality of monetary policy was first carefully examined by Gürkaynak, Sack, and Swanson (2005). The authors identify two monetary policy shocks and look at the response of financial variables to these shocks. Swanson (2021) expands this approach and adds a third shock that appeared during the financial crisis of 2007–2008 — large-scale asset purchase (LSAP) shock. In both papers, the authors use principal component analysis to identify the shocks. We take the same approach in our work and estimate monetary policy surprises from high-frequency data for assets with different maturities, in line with the approach of Gürkaynak, Sack, and Swanson (2005) (hereafter GSS).

Jarociński and Karadi (2020) take another approach to identification, relying on the fact that stock markets react differently to different news announcements. They make use of the observation that in response to a positive regular monetary policy shock, the interest rate increases and the market index decreases, while in response to a central bank information shock, both the interest rate and the market index increase. Another stellar example is the work of Nakamura and Steinsson (2018), which studies the non-neutrality of money, explaining this phenomenon by the fact that Fed announcements contain information not only about monetary policy and interest rates, but also the Fed's outlook on the economy. This leads to puzzling responses to forecasts, which contradicts economic theory. The authors call this the 'Fed Information Effect'. Cieslak and Schrimpf (2019) suggest the similar idea that the central bank's press releases and communications contain information about economic fundamentals. Bauer and Swanson (2020) attempt to explain the 'Fed Information

Effect' and show that the public and the Fed react to the same macroeconomic news. Jarocinski (2021) assumes a non-normal distribution of shocks and finds that it is possible to identify four conceptually different monetary policy shocks. In addition to regular and LSAP shocks, Jarocinski (2021) sees two types of forward guidance shock, similarly to the ideas of Campbell et al. (2012): Delphic and Odyssean forward guidance.

There are many other modern techniques to identify monetary policy shocks. For instance, Miranda-Agrippino and Ricco (2021) study the role of information in monetary policy transmission using forecast-based identification. They define a monetary policy shock as an unanticipated change in market instruments unrelated to the central bank's systematic response to its economic forecasts. This means that the authors distinguish ordinary monetary policy surprises from any future information summarised in projections. Bachmann, Gödl-Hanisch, and Sims (2021) also use central bank information sets to identify monetary policy surprises. They exploit revisions of statistical data to extract exogenous variation in monetary policy.

Kaminska, Mumtaz, and Sustek (2021) apply an affine term structure model to high-frequency changes in the yield curve. Gurkaynak, Kisacikoğlu, and Wright (2020) and Bu, Rogers, and Wu (2021) exploit the idea that the volatility of financial instruments is different in policy announcement periods and in other periods, and they make use of identification via heteroskedasticity. Another approach that is gaining popularity is based on machine learning methods. Munday and Brookes (2021) use computational linguistic tools and examine the efficiency of Bank of England communication. Ter Ellen, Larsen, and Thorsrud (2019) apply textual analysis to Norwegian data and estimate 'narrative monetary policy surprises' for Norges Bank. They use both official communication and accompanying media coverage to extract monetary policy surprises. Finally, Gorodnichenko, Pham, and Talavera (2021) study the influence of press conferences on asset prices. Using computational linguistic techniques, they decompose the tone of the answers given during the Q&A sessions following policy announcements.

Almost all of these papers conclude that the multidimensionality of policy must be taken into account to assess the monetary policy transmission mechanism properly.

The incredible depth and liquidity of the financial markets in the EU and the US offer researchers the opportunity to explore different approaches to studying monetary policy (Gertler and Karadi (2015), Altavilla et al. (2019), and Leombroni et al. (2021)). However, few papers use modern techniques (such as high-frequency identification) to evaluate transmission in emerging economies. Because the financial markets in many such countries are already quite well developed, there should be no problem in studying high-frequency data.

We are familiar with a limited number of such papers. Aruoba et al. (2021) define a monetary policy surprises as the difference between the actual monetary policy decision and the consensus forecast of Bloomberg experts. They then use these surprises in a Bayesian Vector Autoregression to find the responses of macroeconomic variables. There are many issues with such an identification scheme, such as the noisiness of the data, the timing of Bloomberg surveys, and others. Ceballos (2014) also uses the consensus forecast from Bloomberg to evaluate surprises and study how these surprises affect the yield curve. Surprisingly, only a handful of papers study the transmission of monetary policy to interest rates in AEs other than the Euro area and the US. Some rare examples are the works of Kubota, Shintani, et al. (2020) and Nagao, Kondo, and Nakazono (2020), which study unconventional monetary policy in Japan using high-frequency data. Laséen (2020) and Brubakk et al. (2021) study the effects of forward guidance and central bank information on asset prices and economic activity in Sweden and Norway.

INFLATION TARGETING IN RUSSIA Before going further, it is worth offering a brief history of monetary policy in Russia. Russia has a relatively short history of inflation targeting (IT). Only at the end of 2014 did Russia adopt an IT framework. It set an inflation target of around 4%[4] in the medium term. Since then, there have been

[4] https://www.cbr.ru/eng/dkp/

eight policy meetings held each year. As it gained experience in inflation targeting, the Bank of Russia enhanced the transparency of its monetary policy actions. For instance, the Bank now organises a press conference on the day of a policy announcement. After ten days, it publishes a detailed monetary policy report that discusses the decision and provides a careful assessment of the economic outlook both for analysts and for the general public. Additionally, the Bank of Russia recently started publishing the future trajectory of the key rate. These actions have added versatility and transparency to the central bank's policy, and they are intended to help explain the whole process and the motivation behind each monetary policy decision. Thus, the bank's current monetary policy is multidimensional in its aspects.

The rest of the paper organised as follows. Section 2 presents our empirical methodology. Section 3 describes the data. Section 4 presents the results. Section 5 discusses policy implications, and Section 6 concludes.

2 METHODOLOGY

Our analysis relies on three main steps. First, we need to identify monetary policy surprises from the high-frequency data. Then, we extract two types of monetary policy shock from our set of monetary policy surprises. Finally, we estimate the responses of government securities with different maturities, of exchange rates, and of stock market indices in response to these two types of monetary policy shock. In this section, we discuss each of these steps in greater detail.

2.1 *Monetary policy surprises*

Monetary policy surprises are unexpected changes in the prices of certain tradable and liquid instruments in the time around policy meetings or press-conference or during other important events, such as media interviews. This paper analyses only the days of policy meetings for two reasons. First, these days are pre-scheduled, and so the timing is known in advance. Second, it is hard to justify the (un)importance of other public communication events by governors of the central bank, since no systematic method exists in the literature, as of the time of writing, to distinguish the wheat from the chaff *a priori*.

It is assumed that an instrument's price immediately before a meeting captures all publicly available information. The instrument's price after the meeting is assumed to capture all of the new information that becomes available when the decision is announced. A difference between these two prices reflects a monetary policy surprise. Usually, the size of the window around a monetary policy event is from 10 minutes before the meeting to 20 minutes after the meeting (Gürkaynak, Sack, and Swanson (2005), Gertler and Karadi (2015), and Swanson (2021), and others). However, in our paper, we use a daily window because of observed data limitations. Specifically, we calculate the difference in the closing price the day before a policy meeting and the closing price on the day of the policy meeting.

We assume that there are two types of monetary policy shock: regular monetary policy shock, or target shock, ϵ_t^{target} and forward guidance monetary policy shock, or path shock, ϵ_t^{path}. As assets, we use a wide range of instruments (these are discussed in detail in Section 3) that cover the entire yield curve (both exchange-traded and OTC instruments). For each instrument i and each time t (defined as a monetary policy meeting, and not by month), we have monetary policy surprise $s_{i,t}$ and closing price (on the day of the meeting) $p_{i,t}$. We thus have a set of monetary policy surprises containing different information about structural shocks.

$$s_{i,t} = \alpha_{i,target}\epsilon_t^{target} + \alpha_{i,path}\epsilon_t^{path} + \zeta_{i,t}, \tag{1}$$

$$cov(\epsilon_t^{target}, \zeta_{i,t}) = 0, \tag{2}$$

$$cov(\epsilon_t^{path}, \zeta_{i,t}) = 0, \tag{3}$$

$$\hat{s}_{i,t} = \frac{p_{i,t} - p_{i,t-1}}{p_{i,t-1}}. \tag{4}$$

In equation (1), we assume that a monetary policy surprise is the weighted sum of two structural monetary policy shocks (ϵ_t^{target}, ϵ_t^{path}) with some idiosyncratic error ($\zeta_{i,t}$). Equation (4) indicates our assumption that changes in asset prices contain information about monetary policy surprises.

Note that regular monetary policy shock reflects changes in the current monetary policy stance, i.e., it represents any change in the current interest rates. Therefore, it primarily influences the short-term end of the yield curve. The definition of the second shock is a little more open to interpretation. Formally speaking, the second shock represents all changes that are not explained by the first shock. In other words, it could be central bank information or a forward guidance policy. For simplicity, we call these shocks 'forward guidance shocks', or 'path shocks', and these shocks mainly affect the long-term end of the yield curve.

Usually, it is assumed that surprise s_t is uncorrelated with any other events (x_t) that may affect a monetary policy decision (equation (5)) and that it is correlated only with structural shocks ϵ_t^{target} and ϵ_t^{path} (equations (6) and (7)).

$$\mathbf{E}(s_{i,t}x_t) = 0, \tag{5}$$

$$\mathbf{E}(s_{i,t}\epsilon_t^{target}) \neq 0, \tag{6}$$

$$\mathbf{E}(s_{i,t}\epsilon_t^{path}) \neq 0. \tag{7}$$

It is difficult to justify the exclusion restriction assumption (equation (5)) when using daily surprises, because there are many more events that may happen in a day than in a 30-minute window. However, we believe that we can still evaluate monetary policy surprises, because it is highly unlikely that any other macroeconomic news will be released on the same day. There is also the 'week of silence' before policy meetings in Russia. This is a week in which policymakers neither give interviews nor comment on the upcoming decision. We therefore expect that market participants have already formed their expectations, and so, although we understand that the data are noisier when using a daily window, it still contains mainly information about monetary policy decisions.

2.2 *Principal Component Analysis*

After obtaining the set of monetary policy surprises, we need to divide it into the two components of regular monetary policy shock and forward guidance monetary policy shock. To extract these components, we employ Principal Component Analysis (PCA), similarly to the work of Gürkaynak, Sack, and Swanson (2005).

If we have N assets and T monetary policy announcements, we can collect them into $T \times N$ matrix X, where each element $x_{i,j}$ represents a daily surprise for asset j from the announcement made at time i. To extract unobserved factor k, we employ a factor model,

$$X_t = F_t \Lambda + \varepsilon_t, \tag{8}$$

where F_t is a $T \times k$ matrix containing k unobserved factors (in our case, we assume that $k = 2$ and later confirm this by formal tests). Λ is a $k \times n$ matrix of factor loadings. ε_t is the error term. Note that the data used in our PCA are demeaned and standardised before analysis.

We wish to identify matrix F, which includes our k principal components. The model describes the data in X using fewer factors, $k < n$, and so, the model reduces the dimensionality of X by estimating new, uncorrelated factors that explain the maximum possible fraction of the variance of X.

We denote the first two principal components as $\eta_{1,t}$ and $\eta_{2,t}$. These principal components reflect our two monetary policy shocks, regular and forward guidance. However, PCA gives us only a statistical transformation of the original data. There is no reason to think that $\eta_{1,t}$ corresponds with regular monetary policy shock and that $\eta_{2,t}$ corresponds with forward guidance shock. This means that any PCA decomposition is subject to orthogonal rotation (U): any model of $\tilde{F} = FU$ and $\tilde{\Lambda} = U'\Lambda$ gives us similar principal components.

Thus, among all possible rotations U, we need to find the one that corresponds to changes in regular monetary policy and forward guidance. This means that the first principal component, $\eta_{1,t}$, should reflect changes in short-term rates, and the second principal component, $\eta_{2,t}$, should correspond to changes in long-term rates (and any other possible information about the future path of interest rates beyond changes in current interest rates). One way to find a rotation matrix is to place certain restrictions on matrix $\tilde{\Lambda}$, similar to Gürkaynak, Sack, and Swanson (2005). However, we take a slightly different approach here that gives us the same results.

To estimate two monetary policy shocks, ϵ_t^{target} and ϵ_t^{path}, we:

1. Arrange monetary policy surprises $s_{i,t}$ in order $i = 1, 2, 3, \ldots N$ by their maturity, so, $s_{1,t}$ is a monetary policy surprise with the shortest maturity (e.g., government security with one month to expire), and $s_{N,t}$ is a monetary policy surprise with the longest maturity, correspondingly. Then, without loss of generality, only regular monetary policy constitutes a surprise $s_{1,t}$. That it, in equation (1) we assume that $\alpha_{1,path} = 0$.

2. Build an OLS projection on the principal component space, running a regression of $s_{1,t}$ on $\eta_{1,t}$ and $\eta_{2,t}$ and taking fitted values $\hat{s}_{1,t}$. By construction, $\hat{s}_{1,t} = \hat{\epsilon}_t^{target}$.

3. Build orthogonal complement to $\hat{s}_{1,t}$, by regressing $\eta_{1,t}$ on $\hat{s}_{1,t}$ and getting residuals as $\hat{\epsilon}_t^{path}$. After this rotation exercise we end up with two rotated principal components $\hat{\epsilon}_t^{target} = z_t^{target}$ and $\hat{\epsilon}_t^{path} = z_t^{path}$, which we use in our main exercise[5].

3 DATA

The most important task in our analysis is to collect all necessary data. We use several sources of data. First, the data about each policy meeting is taken from the Bank of Russia. Data on all exchange-traded instruments (such as bonds, the stock market index, futures, and exchange rates) are collected from the Moscow Exchange. Third, data on all OTC tradable instruments (interest rate swaps and forward rate agreements) are collected from Bloomberg. Finally, since it is impossible to obtain intra-day data for the Russian OTC market, we use all data on a daily frequency.

POLICY MEETING DATES To identify monetary policy surprises, we collect information dating from the beginning of 2008 to the middle of 2021 (2021 M7) about the dates of Board of Directors' meetings. These meetings are crucial to the formation of monetary policy. As a result of these meetings, decisions are made on the policy rate and the other tools at the disposal of the Bank of Russia based on the current and projected economic situation. However, we have market data only from 2011 onward, limiting our sample of policy meeting dates to start from the middle of 2011. In addition, the Russian financial market was less developed and liquid in the 2000s than it is today, which also motivates our choice of sample length.

The Bank of Russia has been targeting inflation since the beginning of 2014, and that is why the Bank of Russia has increased the transparency and credibility of its monetary policy. For instance, the Bank now holds pre-scheduled policy meetings eight times per annum. Before 2014, policy meetings were irregular and without

[5] We denote estimated values of monetary policy shocks as z_t^j for simplicity

any 'time consistency'. Our sample has information about the exact date and time of publication (down to the minute) and the full text of each press release. We have data for 127 events (policy meetings), but we can use this data effectively only after 2011 because of the above-mentioned data limitations.

HIGH-FREQUENCY DATA To extract policy surprises that may reflect changes in expectations about current and future monetary policy, we make use of data that are available at a high frequency. Notwithstanding the practice of many previous papers, we use daily data to extract monetary policy surprises for several reasons. The main reason is the low liquidity of the government securities market. In contrast to the financial markets of many AEs, Russian government bonds are traded almost exclusively by big institutional investors, with a relatively small share of private investors, which makes it less agile. These often clumsy players are not usually involved in any speculative or high-frequency strategies, and so they may not respond immediately to monetary policy shocks. The second reason for using daily data is that there are no tradable instruments on the exchange market that are closely tied to the interest/key rate other than government bonds. For that reason, we also have to rely on the OTC markets and use several money market instruments for which the underlying assets are the interest or the policy rate.

We understand the limitations of this approach, however. It is harder to justify the exclusion restriction (that monetary policy surprises must be uncorrelated with any other events within the daily window) when using daily data. Therefore, we expect our monetary policy surprises to be noisier than intra-day surprises.

We use the following set of instruments (a full description of the data is given in Appendix B). First of all, we use data on government securities. Here, we apply the Nelson-Siegel approach (the construction of fixed-maturity yield indices directly from the bond data gave us similar results in general). The idea of this approach is that we use information from individual bonds with different maturities to fit the whole yield curve for a given date and time. The Nelson-Siegel methodology is described in detail in Appendix A.

After applying the Nelson-Siegel model (we take an estimated model from the Moscow exchange website), we end up with two sets: (i) the parameters of the model (β_0 serves as a long-term factor, β_1 serves as a short-term factor, β_2 serves as a medium-term factor, and τ is the exponential decay rate) and (ii) a fitted yield curve (from which we can choose any maturity for each date). Although we can obtain fitted values for any maturity, we choose to work with a reasonably extensive (but manageable) set of government bonds yields: 1 month, 3 months, 6 months, 9 months, 1 year, 2 years, 3 years, 5 years, 7 years, 10 years, and 15 years.

Regressing monetary policy shocks on a similar set of variables used to construct those shocks in PCA is incorrect since the same information is contained in shocks and our variables of interest. Therefore, we use another set of tradable instruments to construct the yield curve. For the short-term rate, we use the 1-month OFZ rate, futures on USD/RUB (Si, 3 months to expiration), futures on the RTS (dollar-valued Russian stock market index, 3 months to expiration), and the Moscow Exchange index of government bonds with terms of less than 1 year (RUGBICP1Y, clean price index). Finally, we use interest rate swaps as proxies for the medium- and long-term (from 1 year to 10 years) interest rates.

We prove that applying PCA to this set of variables gives us the first two principal components, which, after rotation, work as our target and path monetary policy shocks. We verify this via several methods. Firstly, we run the formal test of Cragg and Donald (1997) to determine the number of factors. The null hypothesis (H_0) is that the number of factors equals k, rather than the alternative that the number of factors is greater than k. The results presented in Table 1 are clearly in favour of rejecting the null for $k = 0$ and $k = 1$. The null is not rejected for $k = 2$, however, which tells us that the number of factors is at least two. Additionally, using the rule of thumb, we can show that the third eigenvalue becomes less than 1 (which also indicates that it is optimal to use two principal components). Finally, we also show in Figure 1 (bottom right picture) that the first principal component explains about 50% of the variation in the original data, while the first and the second components together explain more than 75%. Adding the third and subsequent components does not significantly improve the share of variance explained. This formal and graphical analysis suggests that there are at least two principal components in the data, which coincides with economic intuition about the interpretation of these components.

Table 1: Test for a number of components

H_0: number of factors equals	degrees of freedom	Wald statistic	p -value
0	36	51	0.00
1	27	40.11	0.00
2	19	30.14	0.12

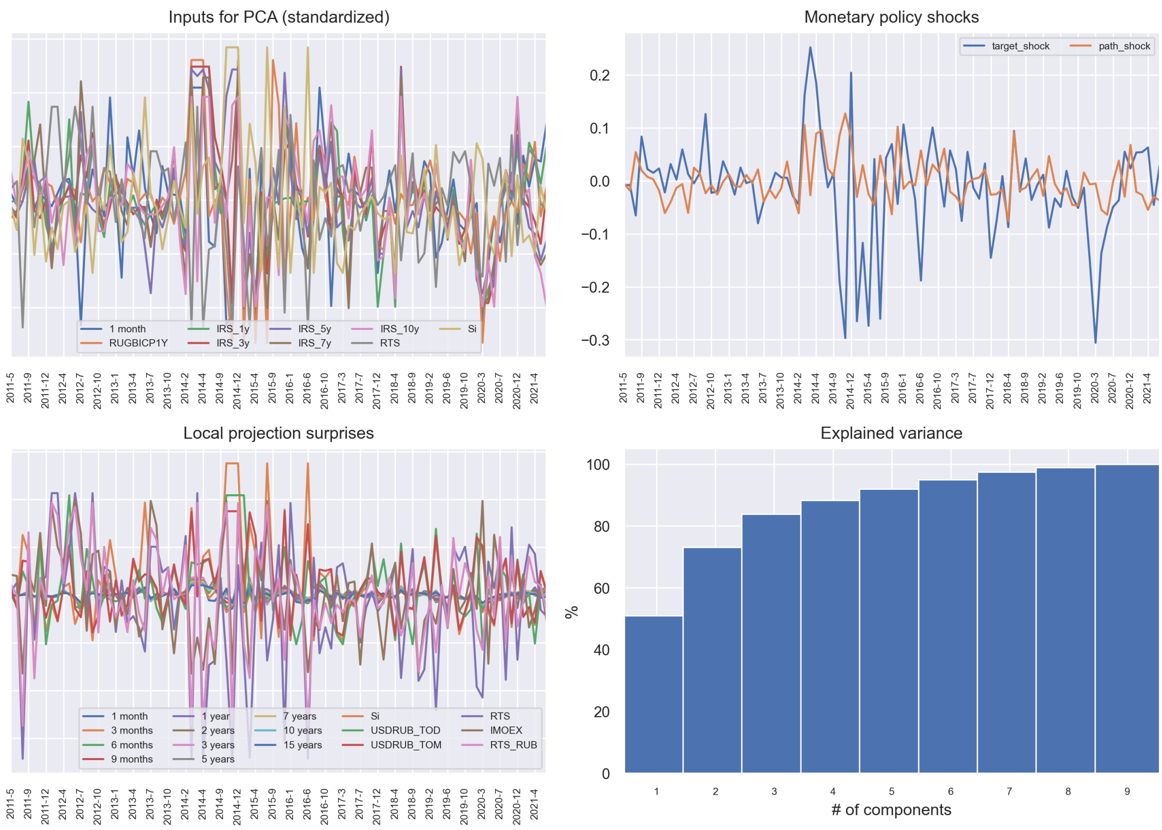

Figure 1: Descriptive figures

Let us present our data graphically. The first row of Figure 1 shows the raw data (the surprises that are used as inputs for the PCA, upper-left picture) and the two extracted and rotated monetary policy shocks (upper-right picture). The biggest shocks occurred during the transition and the volatile period of 2014–2015 and correspond to several unusually sharp instances of monetary policy tightening in response to the surge of inflation in Russia and the subsequent quick reversal of the policy in 2015. There is also a large negative target shock at the begging of 2020, corresponding to the policy easing in the COVID-19 period. Note that path shock is less volatile than the target shock. The positive path shock in June 2018 may be associated with the more negative economic outlook of the Bank of Russia (higher inflation and lower growth) related to the news about the VAT increase in January 2019. The bottom left picture shows data that are used in the local projection exercise (as Δy_t in equation (9)).

We remove extreme values from the data because they negatively influence the estimation. We apply 5–95 winsorisation, replacing extremely low and extremely high values in the data with the values at the 5th and 95th percentiles, respectively. Figure 1 displays the cleaned data, as can be seen from the short horizontal sections (which would otherwise be big spikes). Winsorisation is one of many standard methods to remove outliers. As an alternative, we also check the robustness of our results by employing the 1.5 and 3 interquartile range (IQR) rule and using different instruments for PCA (such as the full set of fitted OFZ values from the Nelson-Siegel model or forward rate agreements). The results remain stable and are available upon request.

As previously mentioned, all inputs to the PCA are daily changes on the day of the monetary policy announcement. The interest rates are taken as the simple difference between the closing value on the day of the announcement and the closing price of the previous day. The variables that are not measured as yields or rates are taken as the percentage change over the same period. The independent variables in the local projection regressions (Δy_{t+h}) are the changes between period $t+h$ and $t-1$. Indeed, for $h = 0$, it is the change on the day of the monetary policy announcement.

At the end of Section 4, we also apply a similar analysis to macroeconomic data such as inflation, industrial production, and exchange rates at a monthly frequency. In

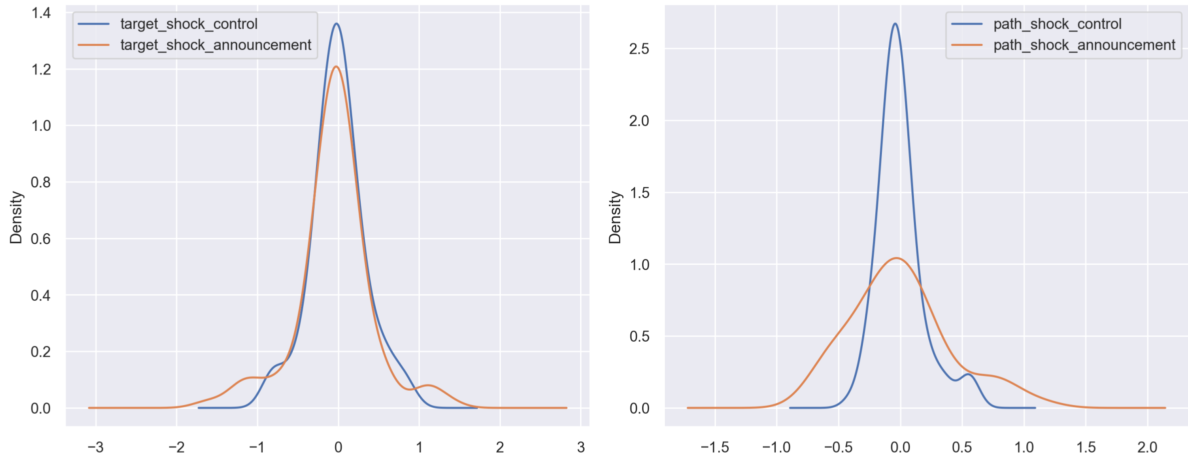

Figure 2: Announcement versus control: 1 week ahead

this case, (Δy_{t+h}) means the change between months, and monetary policy shocks are aggregated to a monthly frequency.

Nevertheless, a final concern about the shocks identified may be about the background noise, similarly to the concerns of Nakamura and Steinsson, 2018; Känzig, 2021. The idea is that non-monetary news may affect the prices of our instruments. This becomes even more important since we consider daily surprises, a larger window than the usual 30-minute surprises.

To address this concern, first, we refer to our local projection exercise and suggest the consideration of any day after day 0 (the day of a monetary policy announcement). The effects on returns on other days are considerably smaller.

Second, we compute our surprises for days other than days of monetary policy announcement. We take the same weekday, but from another week, to form this control sample of monetary policy surprises. To check our surprises for background noise, we compare the densities of surprises computed on the actual days of monetary policy announcement and surprises computed on days shifted one week ahead (Figure 2) and one week backward in time (Figure 3). Other experiments with shifting day of monetary policy surprises are available upon request.

These probability density functions show more variance and fatter tails for both target and path shocks on the days of monetary policy announcements. This indicates that these days are special. Moreover, we can also compute the variance and verify the

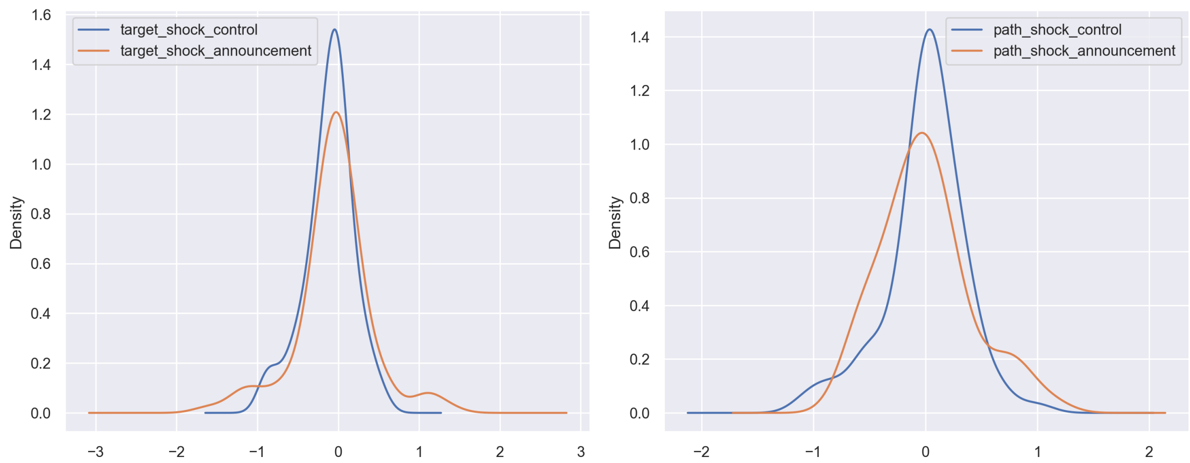

Figure 3: Announcement versus control: 1 week ago

difference via formal test for the announcement and control surprises. However, we still need to be cautious because we use a daily window for surprises, and therefore, some background noise can bias the results.

Finally, after winsorisation, principal component extraction, and factor rotation, we obtain two monetary policy shocks which we use as independent variables in local projections in equation (9). Our dependent variables (Δy_{t+h}) in the baseline model are the set of fitted bonds values (from 1 month to 15 years) and several financial variables: USD/RUB futures, the exchange rate (USD/RUB today and tomorrow), the IMOEX stock market index, and RTS dollar-valued futures on the stock market index. As robustness checks, we also use other independent variables (such as bond indices from Moscow exchanges based on actual (not fitted) yields). The results are available upon request.

4 RESULTS

Our paper is mostly devoted to the effects monetary policy decisions have on financial markets. As financial markets are usually able to process new information relatively quickly and are characterised by high frequency and volatility, we begin our discussion with the short-term effects of different types of monetary policy on financial variables on a daily basis.

Our main results are obtained from a local projection model similar to that used by Jordà (2005). In our work, the local projections take the following simple form:

$$\Delta y_{t+h} = \beta_0 + \beta_{target} z_t^{target} + \beta_{path} z_t^{path} + u_t. \tag{9}$$

Note that t denotes the days of monetary policy decisions (and not simply consecutive days), while h indicates consecutive days. Thus, Δy_{t+h} is the change in the variable of interest between day $t+h$ and $t-1$ around policy meeting day t.

In our first exercise, we look only at the contemporaneous reactions of financial variables. That is, we set $h = 0$, which means that we are analysing the responses of financial variables *on the day* of the monetary policy announcement.

The results are shown in Figure 4. The first column shows the reaction of the bond curve (OFZ-curve), and the second column indicates the responses of the financial variables (the exchange rate and the stock market indices). The first row corresponds to target shock, and the second row corresponds to forward guidance shock. Finally, the last line shows R^2 in the models with just one or both shocks presented. Target shock is normalised in such a way as to influence the current interest rate exactly by +25 basis points (in our case, the shortest available interest rate is the 1-month bond rate). Path shock is normalised to have a +10-basis point impact on the medium-term rate (in our case, the 3-year bond rate).

We believe that 3 years is the horizon for the conduct of monetary policy.[6]. Therefore, we think that changes in the policy rate should be reflected in changes in the short-term rates and that changes in forward guidance, different communication, and so on should be focused on the medium- and long-term rates.

[6]This horizon is embedded in the monetary policy guidelines and is frequently mentioned in the speeches of the members of the Board of Directors.

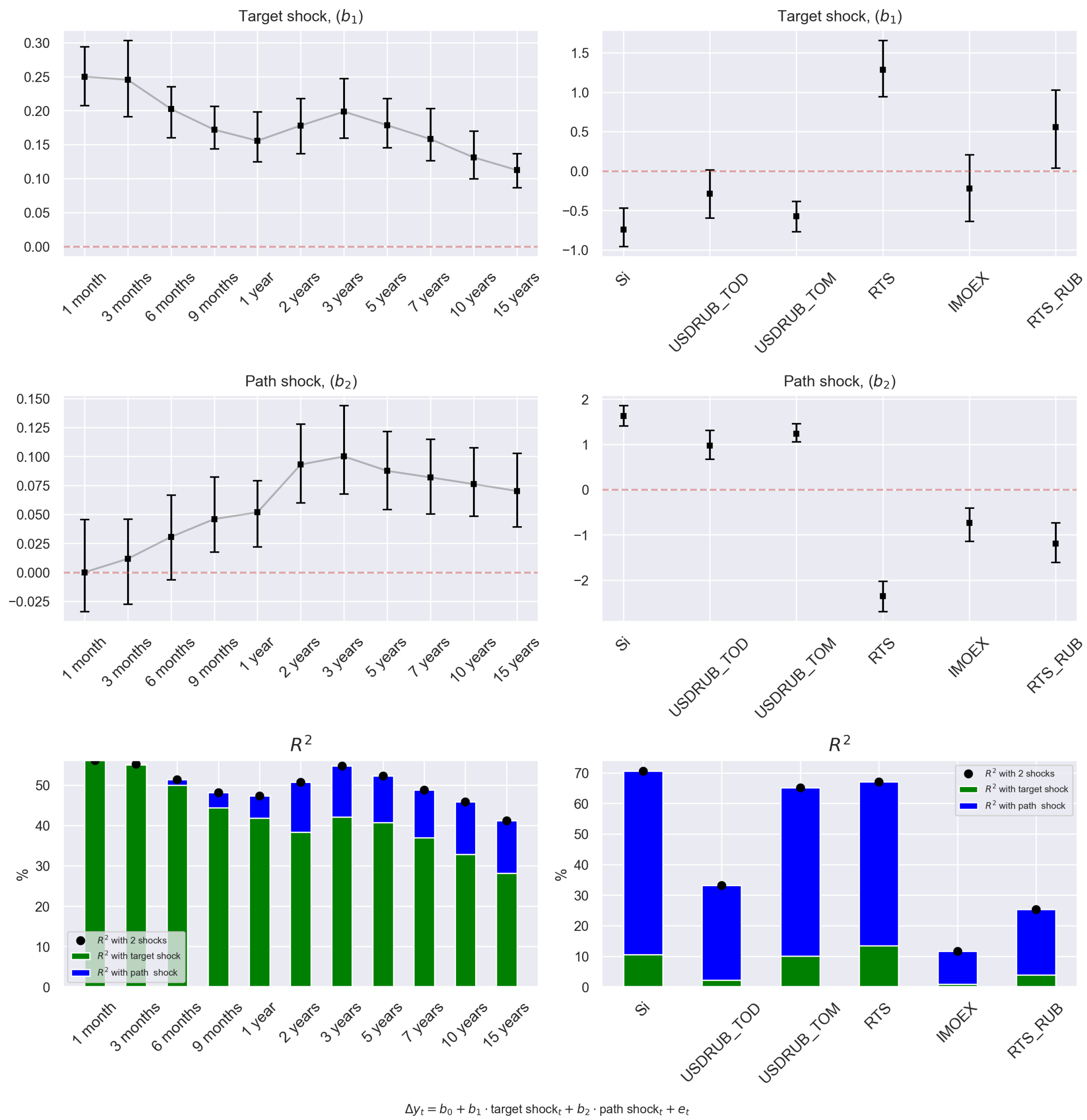

Figure 4: Contemporaneous regressions

The results are somewhat as expected. In response to a target shock, the short-term rates show the greatest reaction. The 3-month bond rate increases almost 1-to-1 (up to 25 basis points), and the response generally fades out along the maturity spectrum. The medium-term rates (from 1 year to 5 years) show an increase from +15 to +20 basis points, and the long-term rates (7 years to 15 years) rise from +10 to +15 basis points.

We do observe some non-monotonic behaviour, however. The reaction decreases for the short-term rates (up to 1 year), rises (from 1 to 3 years), and then declines again.

This movement is interesting, and the local maximum coincides with the horizon length of monetary policy. It is possible that the markets are more interested in the Bank of Russia's medium-term outlook, which adds to the response in this part of the yield curve. We also note that the reaction of the long-term rates (7–15 years) is statistically significant, even if, by construction, target shock must explain the variation in the short-term rates the most.

The financial variables also show the expected reaction. In response to monetary policy tightening, the exchange rates decrease (the ruble appreciates) by about 0.5%, which corresponds to economic theory. This appreciation is almost the same for USD/RUB futures (Si) and exchange rates with 'today' and 'tomorrow' settlements. The reaction of the market index (IMOEX) is not statistically significant at the 5% level, while the futures on the USD-denominated stock index (RTS) increase (primarily because of exchange rate appreciation).

In response to path shock (+10 basis points), the reactions of the short-term rates are insignificant. Although the reaction increases from 9 months and further, it is still relatively small for all the medium- and long-term rates. The medium-term rates (2–5 years) increase by slightly less than +10 basis points, while the long-term rates (7–15 years) increase even less. It appears that path shock is not very potent for interest rates, which somewhat contradicts the previous literature findings on the US and Europe.

However, we see a much stronger reaction from the financial variables in response to path shock. All kinds of exchange rates significantly depreciate (from 1% to almost 2%). The stock market indices decrease. The IMOEX decreases by slightly less than 1%, and the RTS (which encompasses both the decrease in the index and the depreciation of the exchange rate) decreases by more than 2%.

Finally, the last row of Figure 4 contains the marginal R^2s. These bars show the contribution of each of the shocks in explaining the variation of each variable. The green color represents the contribution of target shock, and the blue color is for path shock. These bars confirm that target shock is more important for the interest rate (because most of the variation in the bond rates is explained only by target shock).

Path shock, however, is much more important for explaining the variation in the financial variables.

LOCAL PROJECTIONS While contemporaneous regressions shed light on the current-day reaction, it is uncertain how long the effects of monetary policy last. To answer this question, we re-estimate equation 9 with $h = 0, \ldots, 20$, representing roughly the one-month span of business days ahead.

The results of this exercise are presented in Appendix C. Figures 5–16 present the results of estimation for the all bonds curve and the financial variables. The left subfigure shows the local projection coefficients for target shock, and the right subfigure is for path shock.

Speaking of the long-run (about month) effects of monetary policy on the yield curve, changes in the key rate work as a level-shifter. Once interest rates are changed, they remain at the new level until further changes, assuming that all other things are equal. Indeed, we see that after a Bank of Russia announcement ($h = 0$ on figures), the interest rates rise and usually remain at their elevated levels for both target and path shocks and, expectedly, do not reverse back (at least for the short-term rates). For the long-term rates (5–15 years), we see a much less prolonged impact from target shock. It raises the long-term rates only during the first weeks after the decision, and the effect becomes insignificant after that. However, somewhat in contrast with previous results from contemporary analysis, path shock plays an important role during the whole month after a decision.

The stock market index (IMOEX) declines significantly only due to path shock, with the effect lasting less than two weeks. On the other hand, the RTS (USD-denominated futures) increases in response to target shock (but the effect disappears after a couple of days) and significantly and persistently declines after path shock. The exchange rates behave similarly to one another: they consistently appreciate in response to target shock and depreciate in response to path shock. Any of violation of level-shifting behavior may be attributed to the background noise and new information in the days after monetary policy meetings.

ROLLING OLS We note that our sample of monetary policy events is quite heterogeneous. Indeed, the Russian economy is much more volatile than the AEs usually analysed in the literature. Several big shocks and structural changes, such as the switch in the monetary policy regime in 2015, can change monetary policy transmission and introduce some bias to our results. This type of concern, for example, has been examined for the US by Paul (2020), who exploits a time-varying parameter model and studies monetary policy transmission to asset prices. It turns out that monetary policy effects are not constant over time, and this fact must be taken into account.

To examine this issue in our data, we estimate the same equation (9) with $h = 0$ on a rolling window. We set the length of the window at 40 monetary policy events (which approximately corresponds to five years of monetary policy). The results are presented in Appendix D in Figures 17–28. The left subfigures show the estimated coefficients for target shock on a rolling-window basis, the middle subfigures represent path shocks, and the right subfigures show the marginal R^2 for every window.

This exercise serves as a robustness test. As can be seen, all the coefficients are relatively stable throughout the whole sample, suggesting a persistent transmission process from policy to the financial market. This also means that we do not have significant outliers influencing our main results. One exception is the slight break in the coefficients at the end of 2019 into the beginning of 2020, which is presumably due to the fact that this is the last period for which 2015 is still contained in the rolling sample. 2015 was a transitional year between two monetary policy regimes and is characterised by high interest rate volatility.

Further, in confirmation of past results, we see that the majority of interest rate variation can still be explained only by target shock during any subsample. At the same time, the variation of the stock market indices and exchange rates is better explained by path shock.

MACROECONOMIC VARIABLES Finally, it is important to assess not only the reaction of the financial markets to monetary policy, but also the reaction of macroeconomic variables. Monetary policy in Russia aims to ensure price stability, and thus the Bank of Russia needs to understand how monetary policy is transmitted into inflation. The reaction of other macroeconomic variables to monetary policy may also be a subject of interest.

Using a similar regression as in equation (9), we estimate the model on a monthly frequency. Now, however, index t denotes the month of a monetary policy announcement, and h is the number of months after the monetary policy announcement. To aggregate monetary policy surprises from a daily to a monthly frequency, we assign a monetary policy surprise to a given month if a monetary policy decision took place in the month, and we assign a zero otherwise.

We consider the following set of dependent macroeconomic variables: the consumer price index (CPI), industrial production (IP), and the exchange rate. The results are presented in Appendix E. Figures 29–31 present the results of the estimation. The left subfigures show local projection coefficients for target shock, and the right subfigures represent reactions to path shock.

We see that these results are counterintuitive if we compare them with our event-study methodology. Previously, the exchange rate depreciated in response to path shock, while now it appreciates. This result requires further research. The reasons may vary from the use of different samples (in event studies, we do not have zero surprises, while in the monthly data, we do) to the omission of certain control variables in the monthly regressions.

We see that an unexpected rise (tightening) in either of the two dimensions of monetary policy negatively affects the CPI. The period for transmission from the decision to the CPI is about one year. Indeed, 11–12 months after a decision, we see that the CPI declines in response to both target and path shocks. Then the CPI quickly recovers to its previous level. This is, to some extent, similar to the result of Gertler and Karadi (2015), but it contradicts Bachmann, Gödl-Hanisch, and Sims (2021), who finds that the CPI persistently declines.

Finally, we do not observe any significant reaction from industrial production, while the exchange rate reacts only to path shock and appreciates almost immediately after a decision.

To sum up, the CPI and the exchange rate respond to changes in monetary policy in the usual way. When the Bank of Russia tightens monetary policy unexpectedly, the CPI starts to slow down, while the exchange rate appreciates.

5 DISCUSSION

POLICY IMPLICATIONS Our results shed light on the effectiveness of monetary policy in Russia and may be relevant in the future conduct of monetary policy. We find that target shock is important for interest rates, influencing both the short-term and the long-term rates. Path shock turns out to be most important for financial variables such as the exchange rate and the stock market indices. The transmission period from a decision to inflation is about one year.

These distinct roles for target and path shocks require additional attention from a policy perspective. Based on this analysis, we can conclude that it is important to pay considerable attention to forward guidance, communication, and other policies that may be connected with path shock. This may require the Bank of Russia to continue developing transparent monetary policy tools, because at this time, the effects of monetary policy on interest rates primarily result from changes in the key rate. According to the best practices of other central banks, this is not the only option for changing market interest rates.

We emphasise, however, that the impact of path shock (even with a similar magnitude as target shock) on interest rates is smaller than expected. In contrast, the effect of path shock on financial markets with a similar magnitude is inadequately high.

We assume that target shock changes have a similar magnitude as those from an unexpected change in the policy rate, given its high correlation with surprises for the shortest-term rates. However, we do not know the size of a 'typical' path shock. Based on the data, the volatility of path shock is considerably smaller than that of target shock. Arguably, path shock may have even less influence, given its actual average size. For instance, if, as a result of a monetary policy announcement, path shock changes ten times less than our estimate (by 1 basis point instead of 10 basis points), then the effects on the long-term rates would be economically negligible.

However, the source of the unresponsiveness of interest rates to path shock may come from the public side. We see that path shock is important for financial variables, meaning that market participants pay attention to future policies rather than just to the latest change in the key rate. Thus, the problem may arise from a misunderstanding between the public and the Bank of Russia: market participants may not fully understand the economic and rate outlook, or they may be unsure of the meaning of the bank's current policy agenda. This inability to efficiently and adequately adjust expectations about the long-term rates could be the reason why we see only a small impact.

LIMITATIONS Before concluding, we will make several important remarks and note the limitations in our data and results. Russian monetary policy is quite heterogeneous: its effects vary substantially between the regions of the country (Napalkov, Novak, and Shulgin (2021)). This may be a problem because the estimated responses of the macrovariables considered to identical shocks may be region specific. Inflation expectations are also not well anchored in Russia, and therefore any rise in inflation usually leads to higher inflation expectations. The explanation of the reasons for the non-anchoring of inflation expectations is beyond the scope of our paper. Nevertheless, to some extent, it hinders the transmission mechanism from monetary policy to the financial markets and the real sector.

The availability of trading data is also limited in Russia. As compared to the US, there are only a couple of liquid futures on the Moscow exchange: on the stock market index, on the USD/RUB exchange rate, on Brent oil, and on several Russian companies' shares. None of these futures is linked to an interest rate. The same story holds for the Russian bond market. Bonds are often not liquid enough, with a very small number of trades each day, even if it is the day of a monetary policy announcement.

However, the OTC market is much better. There, commercial banks actively trade with one another using different interest rate swaps and forward rate agreements. Even so, we cannot be sure that the prices of these trades reflect unexpected changes in the key rate with high precision. Banks use the OTC market for different reasons, such as hedging their risks, meeting the regulator's requirements, and so on. Additionally, the Russian banking sector is somewhat segmented, and these trades on the OTC market are usually between the 10 largest banks.

Based on the limitations of our data, we conduct our analysis using only daily data, keeping in mind that this is a wide window for high-frequency identification. However, even if our estimates may be noisy, they are still quite consistent on different subsamples, with different approaches to the handling of outliers, and with different input sets for the PCA.

Furthermore, our database of monetary policy announcements contains only days on which monetary policy decisions were made. However, policy communication from members of the Board of Directors also happens on other days, through various media interviews, press reports, and so on. It is possible and desirable to include days with other significant events in our database to increase the accuracy of the estimates.

Additionally, several authors (Campbell et al., 2012; Gürkaynak, Kara, et al., 2021, among others) divide path shock into two distinct components, which are usually called Delphic and Odyssean forward guidance shocks. Both of these shocks influence the long-term rates similarly, however, they differ in the reactions of market indices.

Delphic forward guidance leads to higher market indices, while Odyssean forward guidance leads to lower market indices. To divide our shocks into a more detailed structure, we need tradable inflation-linked products. Such instruments exist in the Russian financial market, but they are relatively new, less liquid, and do not have long price histories.

Finally, as we previously mentioned, our sample consists of two periods with different monetary policy regimes. It is important to understand that before 2015, the Bank of Russia did not have an inflation target, and thus we should expect a different type of transmission mechanism during this period. However, the robustness test on the rolling subsamples shows that the results are quite stable across the pre-2015 and post-2015 periods.

6 CONCLUSION

This paper discusses the effects of monetary policy shocks on financial markets and macroeconomic variables. Using high-frequency monetary policy surprises taken from tradable financial instruments, we construct two orthogonal monetary shocks. The first – target shock – is connected with changes in the short-term interest rate and can be interpreted as a standard policy rate shock. The second – path shock – is connected with other aspects of monetary policy, such as forward guidance, communication, central bank information, and so on. We then use these shocks as independent variables in local projection regressions and study the short-term and dynamic effects on financial variables. We also aggregate these shocks to a monthly frequency and analyse the responses of macroeconomic variables.

As a result, we show that target shock primarily influences the term spreads and explains most of the variation of rates along the entire yield curve. A standard monetary policy step of 25 basis points raises short-term rates by 20–25 basis points. Surprisingly, we find an effect on long-term yields, too. Target shock leads to an increase in yields on 7-15 year bonds by 10–15 basis points. Interestingly, this indicates that market participants adjust their long-term expectations based on changes in the current rate.

However, path shock has a very limited impact on interest rates and mostly influences financial variables such as exchange rates and stock market indices. Path shock of much less than 10 basis points leads to a statistically significant depreciation of the exchange rate (more than 1%) and a decrease in stock market indices (1–1.5%).

We also do not observe a price puzzle, as has usually been found in previous papers on Russian monetary policy. Apparently, high-frequency identification and accounting for the multidimensionality of monetary policy do their work to resolve the price puzzle. Our estimates suggest that an inflation reaction happens about one year after a decision, which coincides with the Bank of Russia's predictions.

We also highlight the important distinction in the impact of these two shocks on the variables. It is clear that target and path shocks have different underlying sources, which suggests that both additional attention from the policymaker and further research are needed.

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APPENDIX

A NELSON-SIEGEL METHODOLOGY

This appendix briefly describes the Nelson-Siegel model. The idea of this model is that we can consider each day in our sample separately. For each day, we have a number of tradable bonds with corresponding maturity dates (τ) and yields (y_t). Here, t refers to separate days. We can estimate the following model for each t separately (the following specification is from Diebold and Li, 2006):

$$y_t(\tau) = \beta_{1,t} + \beta_{2,t}\left[\frac{1-\exp\left(-\lambda\tau\right)}{\lambda\tau}\right] + \beta_{3,t}\left[\frac{1-\exp\left(-\lambda\tau\right)}{\lambda\tau} - \exp\left(-\lambda\tau\right)\right] \tag{10}$$

After the estimation of equation (10), we end up with the parameters of the model (β_0 serves as a long-term factor, β_1 serves as a short-term factor, β_2 serves as a medium-term factor, and τ is the exponential decay rate). Note that these parameters differ for each day (t), meaning that these parameters can fully describe the entire yield curve in each day.

Therefore, for each day (t), we can obtain a fitted yield curve (from which we can choose yields for each date and for any maturity). Although we can obtain fitted values for any maturity, we choose to work with a reasonably extensive (but manageable) set of government bond yields: 1 month, 3 months, 6 months, 9 months, 1 year, 2 years, 3 years, 5 years, 7 years, 10 years, and 15 years.

B DATA

In table 2 you can see the description of data used.

Table 2: Data

Variable	Decription
1 month - 15 years OFZ bonds yields	Fitted values from Nelson-Siegel model, parameters are taken from Moscow exchange.
1 year - 10 years IRS	A vanilla interest rate swap is an agreement between two counterparties to exchange cashflows (fixed vs. floating) in the same currency. This agreement is often used by counterparties to change their fixed cashflows to floating or vice versa. The payments are made during the life of the swap in the frequency that is pre-established by the counterparties.
Si	Futures on USD/RUB with expiration in 3 months
RTS	Futures on dollar-valued Russian stock market index with exparation in 3 months
USDRUB_TOD	Today USD/RUB exchange rate
USDRUB_TOM	Tomorrow USD/RUB exchange rate
IMOEX	Spot value of Russian stock market index
RUGBICP1Y	Bonds index with less than 1 year duration, calculated by Moscow Exchange
CPI	Consumer price index, monthly seasonally adjusted
IP	Industrial production index, monthly seasonally adjusted
Exchange rate	US Dollar/Russian Rouble FX Spot Rate, monthly

C LOCAL PROJECTIONS

This appendix presents the extended results of the local projection exercise. Here, we estimate Equation (9) with $h = 0, \ldots, 20$, where h represents one business day. This means that, for each h, the dependent variable is the cumulative growth of y from t to $t + h$. That is, if $h - 0$, then y is the change from $t = 1$ to t on the current day of announcement.

The left subfigures in Figures 5–16 show the coefficients for target shock (normalised to a 25-basis point reaction from the shortest rate). The right subfigures show the coefficients for path shock (normalised to 10 basis points from the 3-year bond yield).

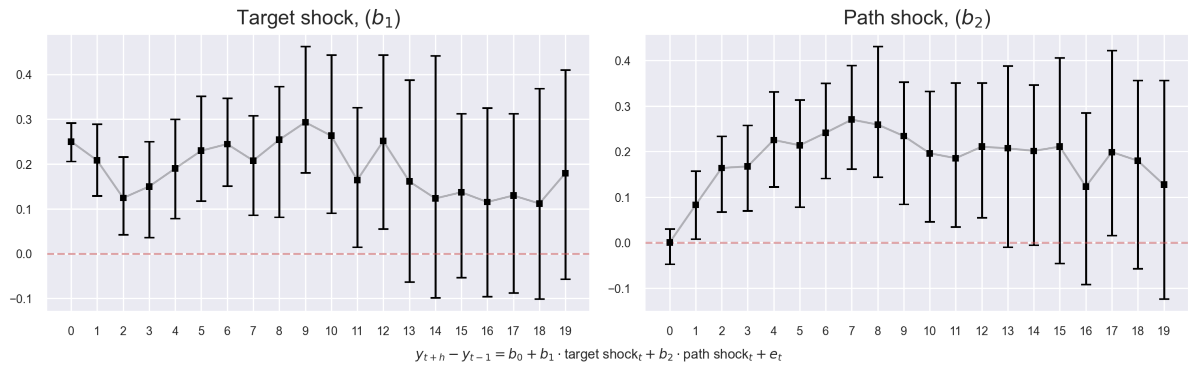

Figure 5: Local projections: 1 month bond rate

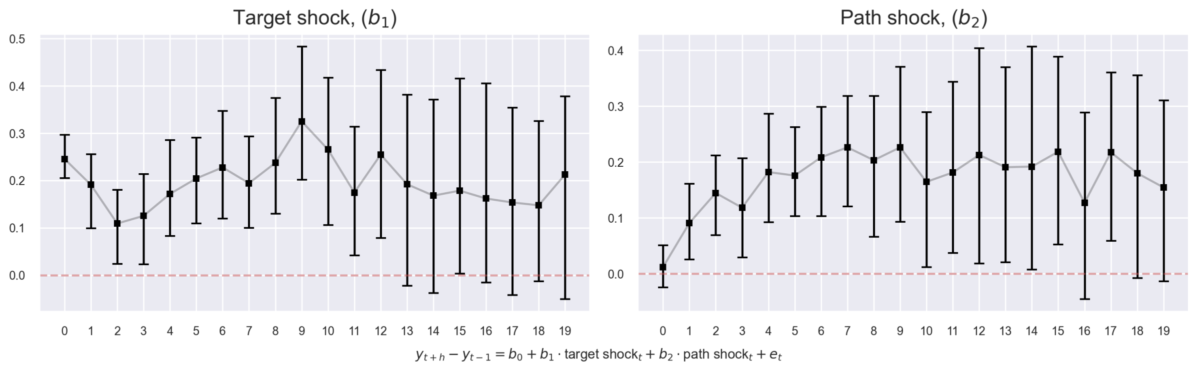

Figure 6: Local projections: 3 months bond rate

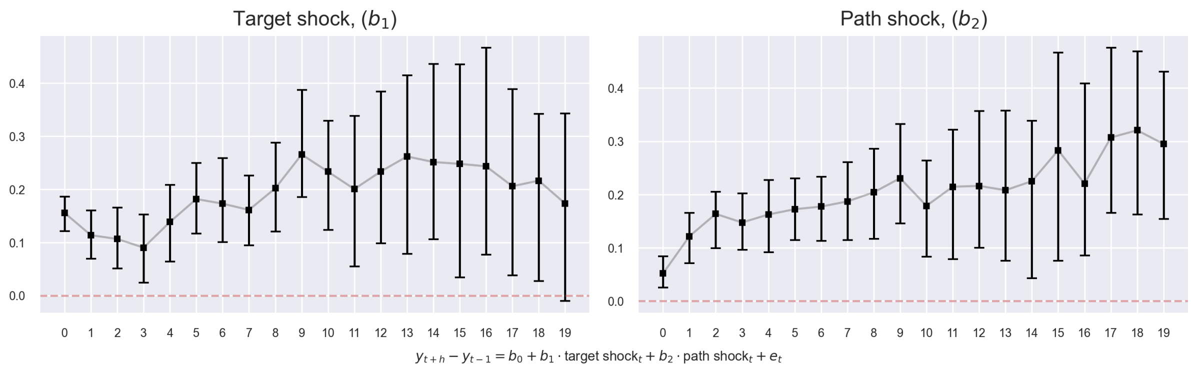

Figure 7: Local projections: 1 year bond rate

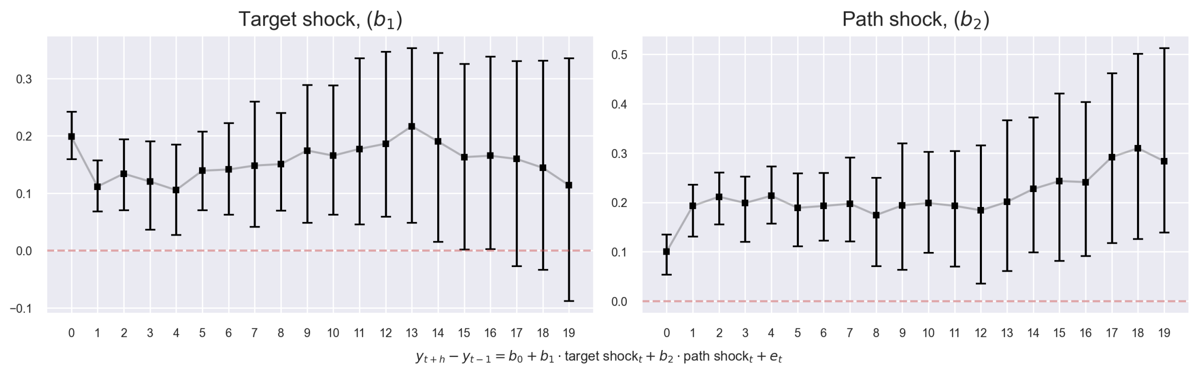

Figure 8: Local projections: 3 years bond rate

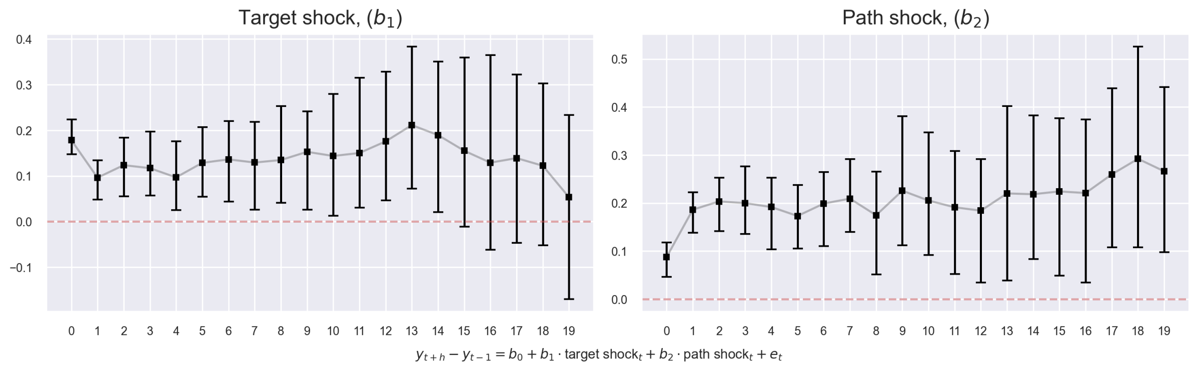

Figure 9: Local projections: 5 years bond rate

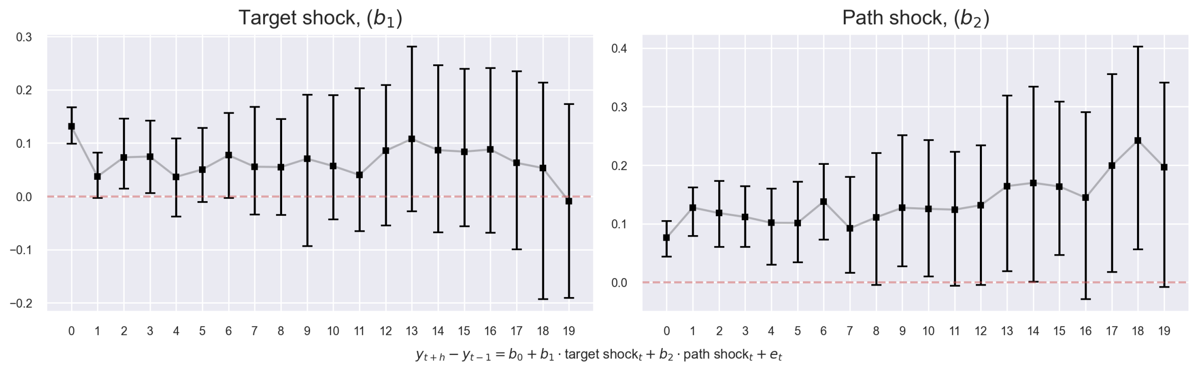

Figure 10: Local projections: 10 years bond rate

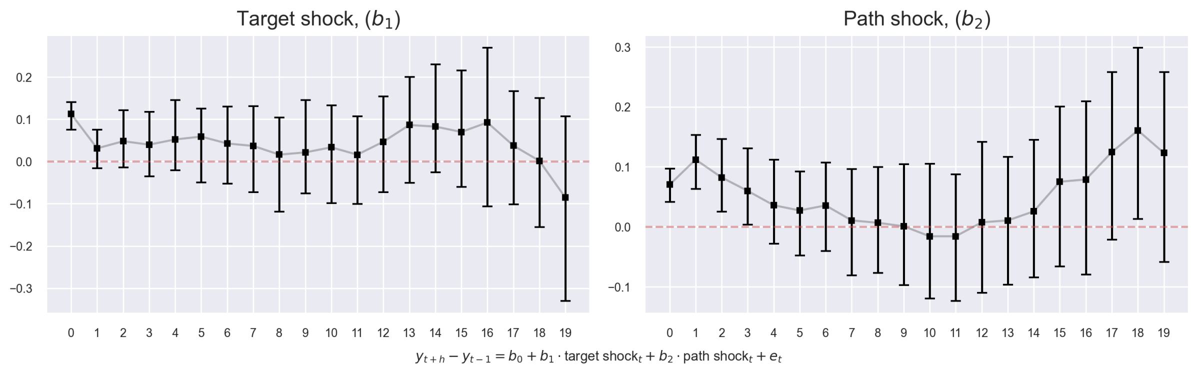

Figure 11: Local projections: 15 years bond rate

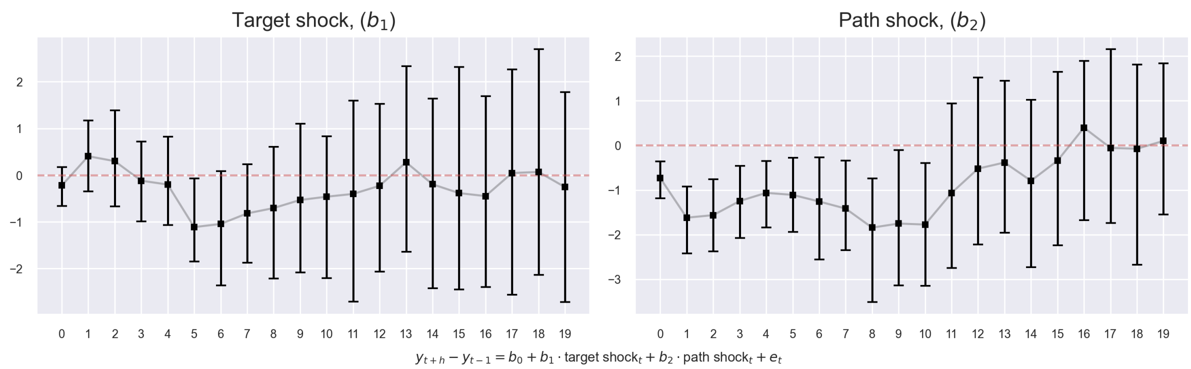

Figure 12: Local projections: IMOEX stock market index

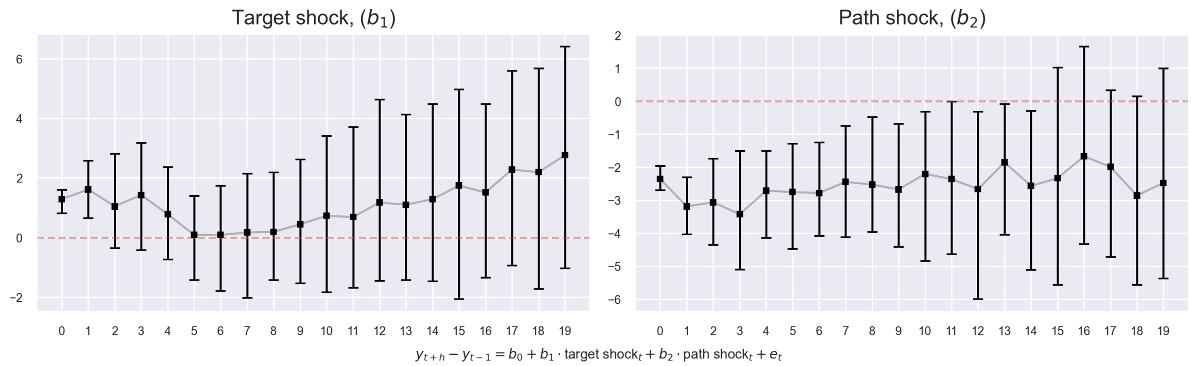

Figure 13: Local projections: RTS futures

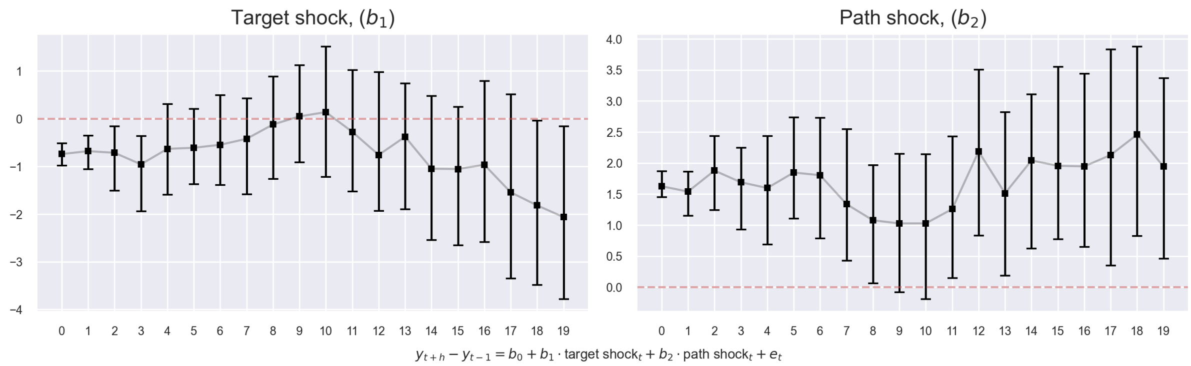

Figure 14: Local projections: USD/RUB futures

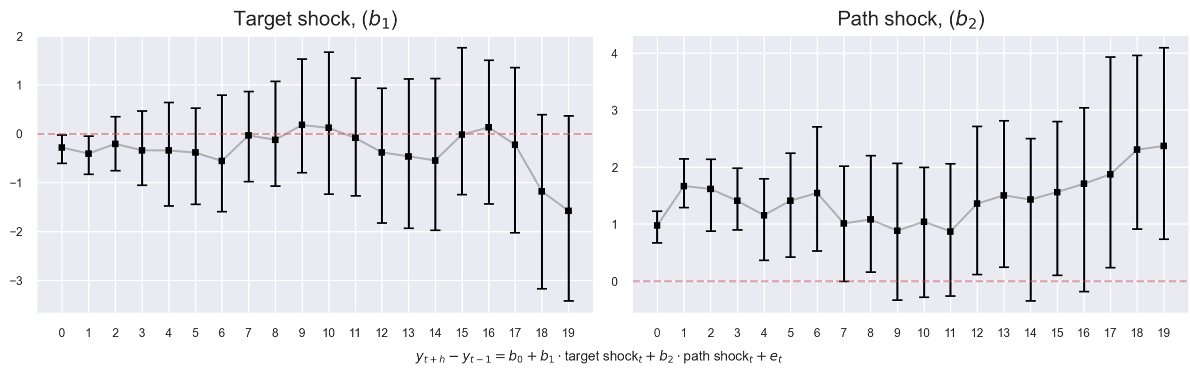

Figure 15: Local projections: USD/RUB today exchange rate

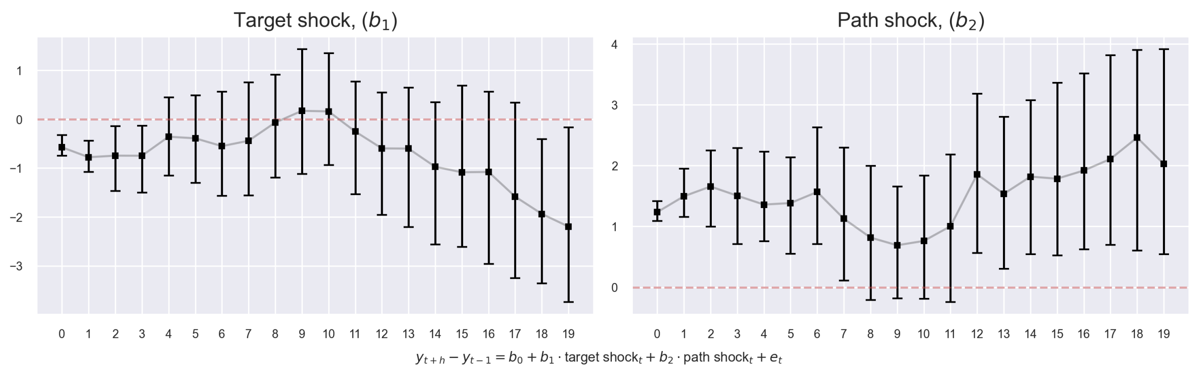

Figure 16: Local projections: USD/RUB tomorrow exchange rate

D ROLLING OLS

This appendix presents the extended results of the rolling window subsample analysis. Here, we estimate Equation (9) with $h = 0$ for the 40 consecutive points (days) in our sample.

The left subfigures in Figures 17–28 show the coefficients for target shock (normalised to a 25-basis point reaction from the shortest rate). The right subfigures show the coefficients for path shock (normalised to 10 basis points from the 3-year bond yield).

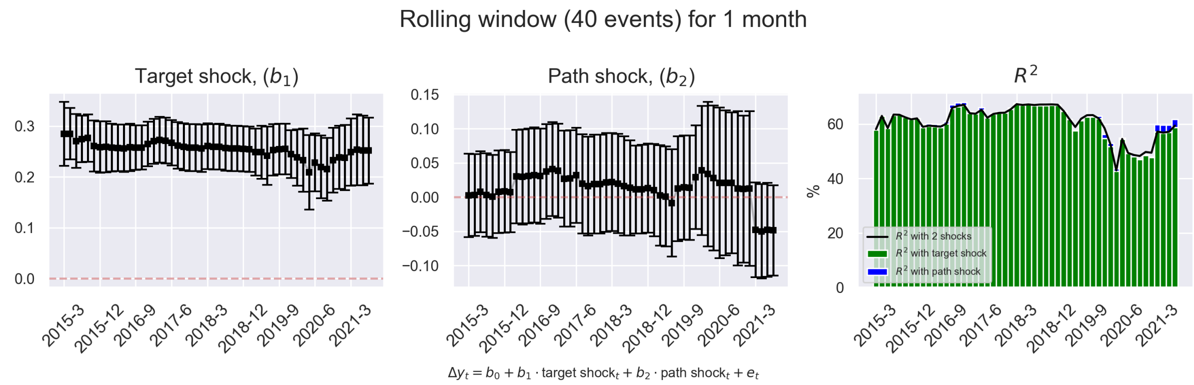

Figure 17: Rolling window: 1 month bond rate

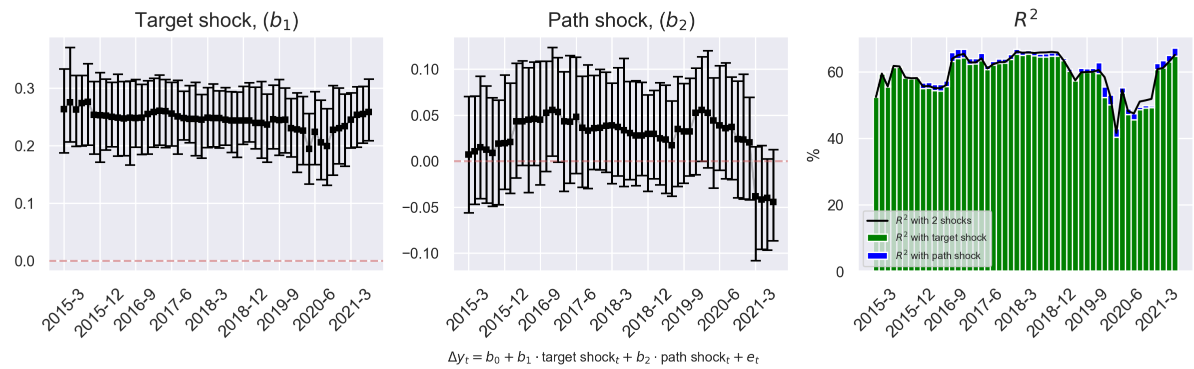

Figure 18: Rolling window: 3 months bond rate

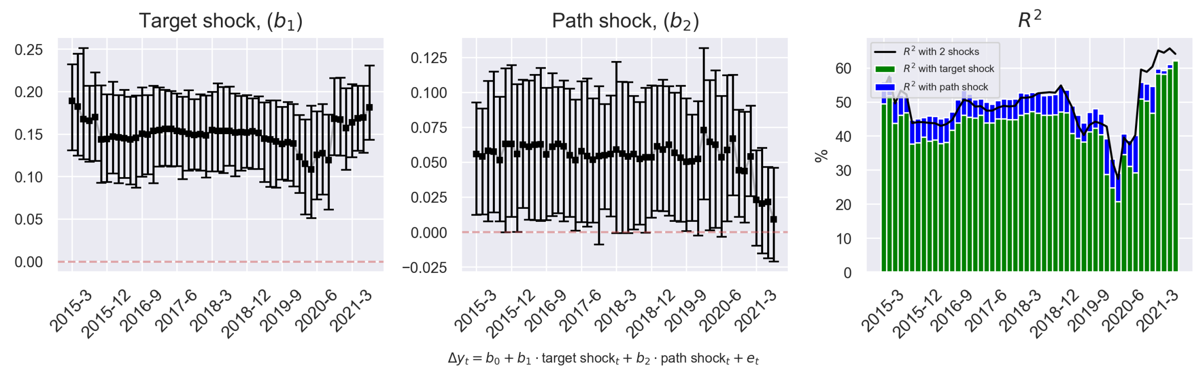

Figure 19: Rolling window: 1 year bond rate

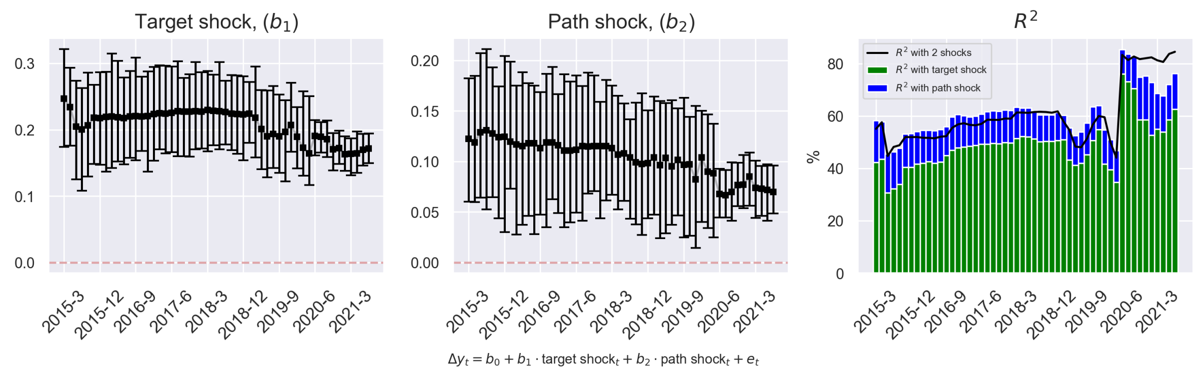

Figure 20: Rolling window: 3 years bond rate

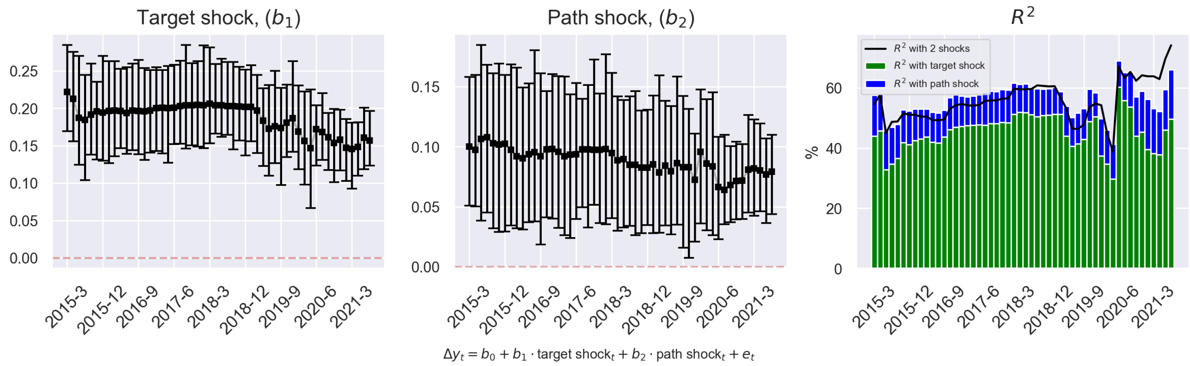

Figure 21: Rolling window: 5 years bond rate

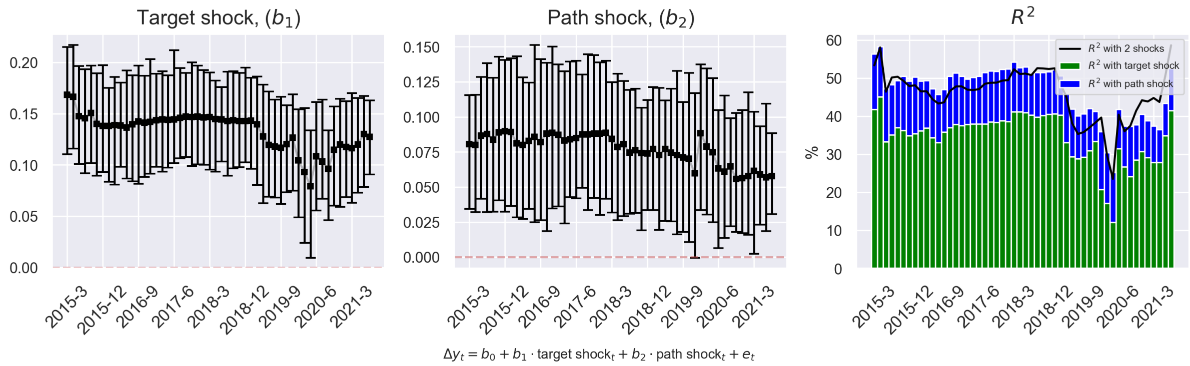

Figure 22: Rolling window: 10 years bond rate

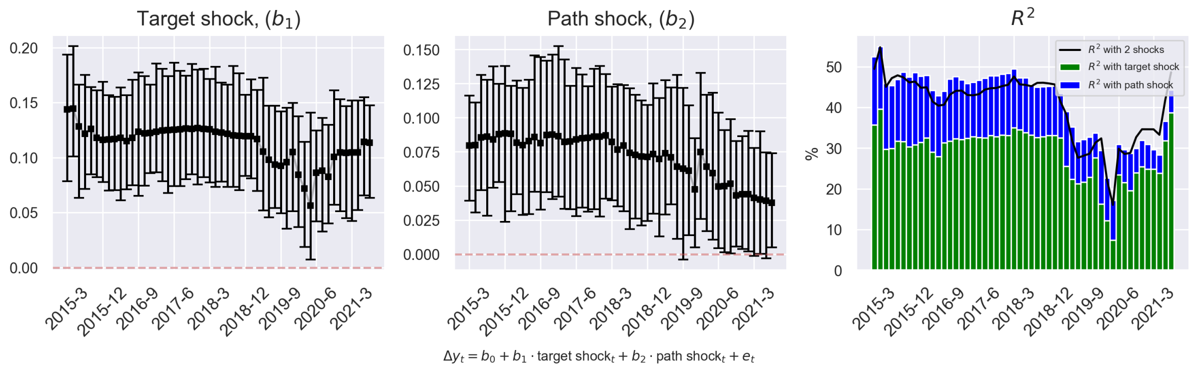

Figure 23: Rolling window: 15 years bond rate

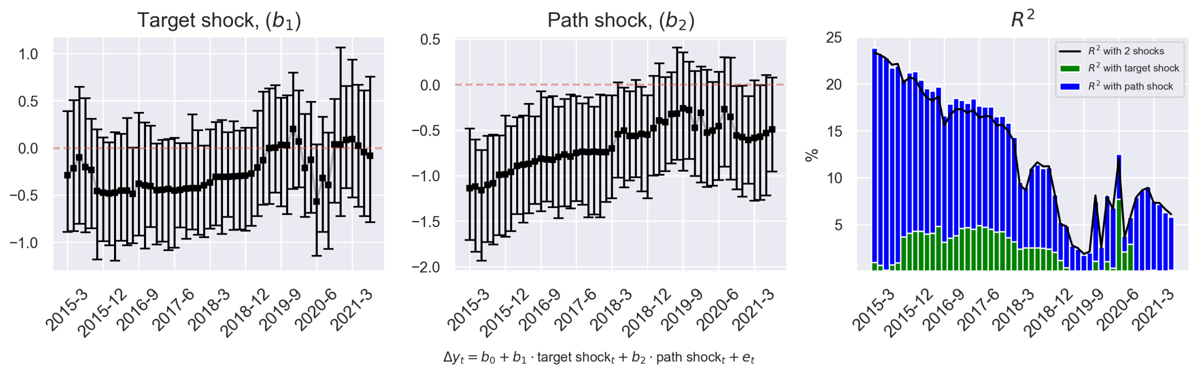

Figure 24: Rolling window: IMOEX stock market index

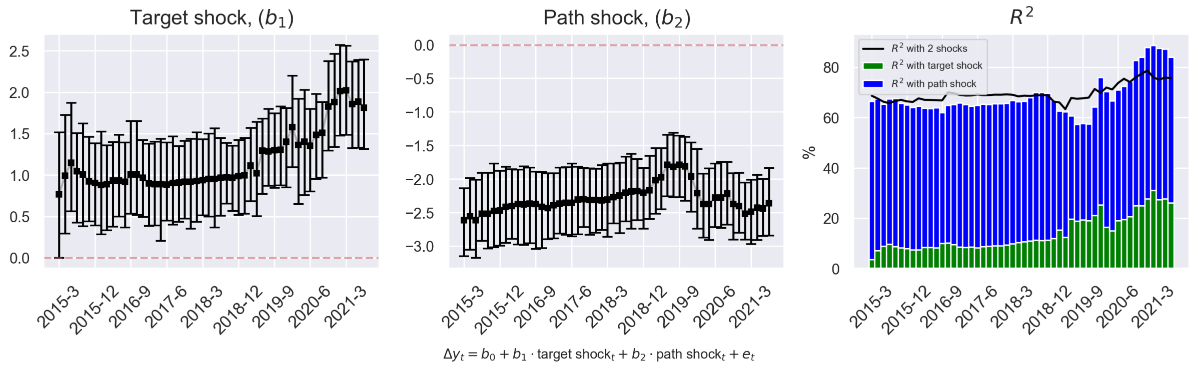

Figure 25: Rolling window: RTS futures

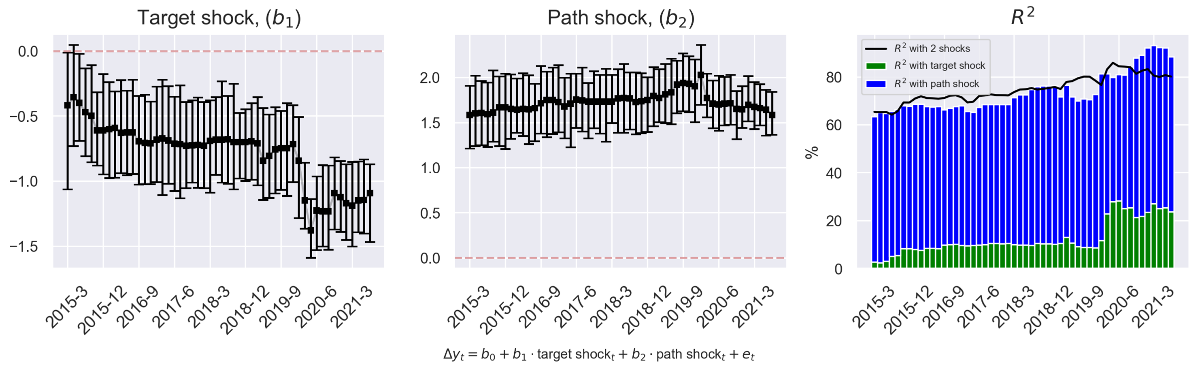

Figure 26: Rolling window: USD/RUB futures

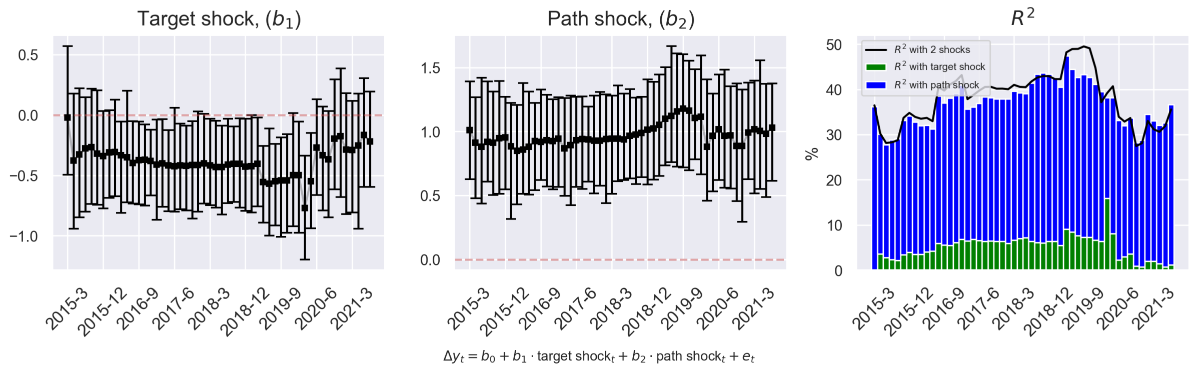

Figure 27: Rolling window: USD/RUB today exchange rate

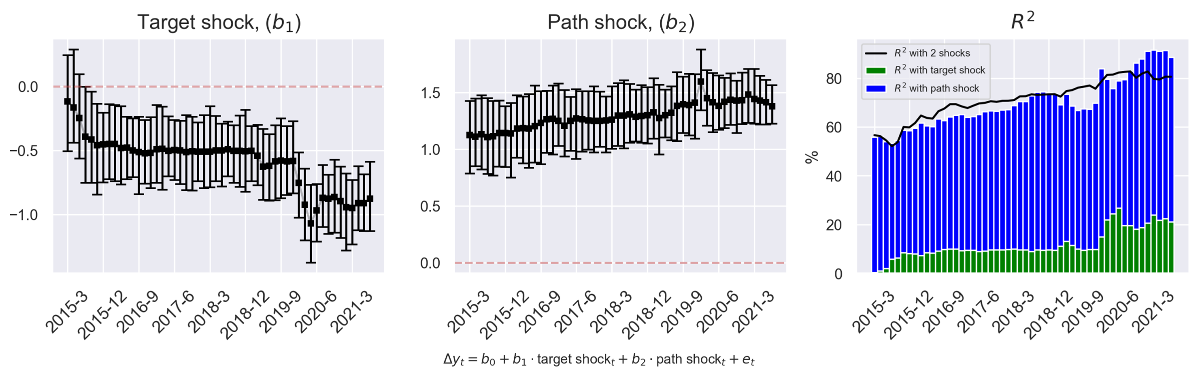

Figure 28: Rolling window: USD/RUB tomorrow exchange rate

E MACROECONOMIC VARIABLES

This appendix presents the extended results of the local projection on macroeconomic data. Here, we use monthly data and aggregate monetary policy shocks to a monthly frequency. If there are one or more monetary policy announcements in a given month, we assign these shocks to the month. If there are no monetary policy events, we assign a zero value for monetary policy shocks to the month.

We then estimate Equation (9) with $h = 0, \dots, 20$, where h is a number of months. This means that, for each h, the dependent variable is the cumulative growth of y from t to $t + h$. That is, if $h = 0$, then δy is the change from $t - 1$ to t in the current month.

The left subfigures in Figures 29–31 show the coefficients for target shock (normalised to a 25-basis point reaction from the shortest rate). The right subfigures show the coefficients for path shock (normalised to 10 basis points from the 3-year bond yield).

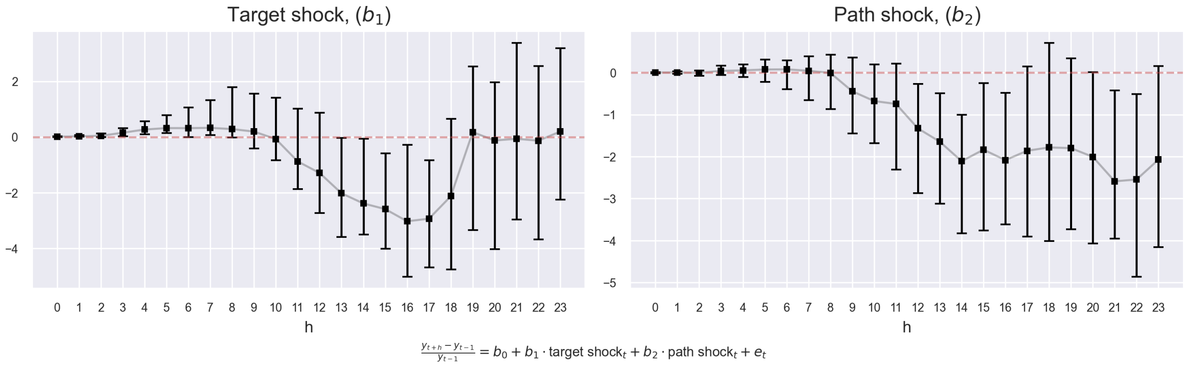

Figure 29: Local projections: CPI

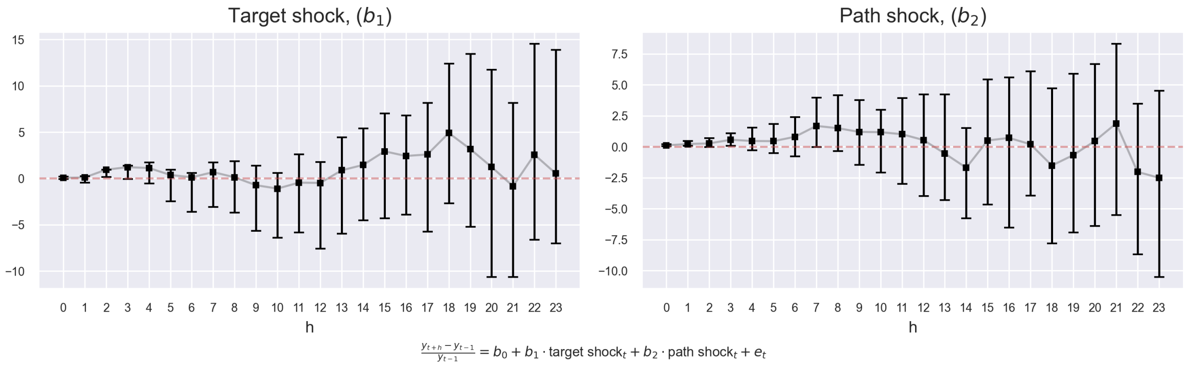

Figure 30: Local projections: Industrial production

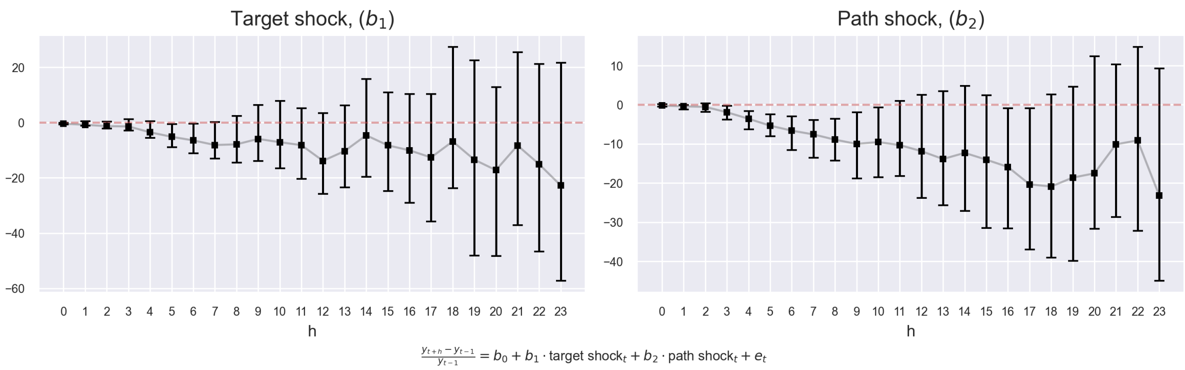

Figure 31: Local projections: Exchange rate