

Investigation of factors affecting the Russian government bond yields

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Abstract

This article investigates the behavior of the Russian government bond yields and its sensitivity to a selected range of macroeconomic, monetary, international and event factors. At first, relevant factors to be analyzed as underlying determinants of interest rates' movements are examined and singled out according to the analysis of specific features of the GKO-OFZ market development and empirical and theoretical literature review. Then it is tested whether and to what extent interest rates of various maturities reflect changes in economic indicators and information from economic events. The analysis concerns both individual and joint, short-term and long-term influence of factors under study, with emphasis to the most informative determinants of yields. In whole the results of the empirical study using monthly data from 2003 to 2009 indicate a major significant role of changes in monetary factors, notably the minimum repo rate and the interbank interest rate, as well as of foreign exchange rate risk factor. Joint influence of theoretical fundamentals, namely inflation and its expectations, exchange rate and money supply growth, explain less than a third of bond yields movements. On the other hand, no importance of GDP and domestic debt growth as well as of external risk factors, such as oil prices, foreign interest rates and changes in international reserves is found. Also the results provide evidence for the fact that most government bond yields respond to certain political and economic events and reflect crisis changes of the market.

Key words: Russian government securities market, bond yields, interest rates, sensitivity to factors

1. Introduction

The behavior of the government bond yields is one of the key indicators of the sovereign debt market's development and state, traditionally being a benchmark for the overall level of

interest rates in the economy, future trends and changes in valuation of financial instruments, indicating risk-free rates and current real interest rates in financial market.

Hypotheses of the term structure of interest rates try to explain the relative positions of bond yields with different maturities, correlation of nominal yields, one or another form of the yield curve. Accordingly, we can assume that the rates of return on bonds of different maturities move under the influence of common factors, but the significance and strength of their effects vary. Identification of such determinants and understanding of their impact on the yields of government bonds is important when making decisions in financial markets, particularly in crisis situations and constantly evolving new methods of financing. Objectively, among explanatory variables may be the parameters of economic development, changes in fiscal and monetary policy, inflationary expectations, the impact of information from external markets, as well as the features of the market itself. Along with this, an important question may arise: whether the yields are really, to some extent, exposed to economic factors or other unaccounted sources of information, such as market sentiments, investors' subjective purposes or exact targets of government regulators prevail in the yield curve movements.

In whole, recently little research addresses the problem, especially in emerging markets¹, owing to rather short history, illiquidity, difficulties of gathering data and narrow data scope. Therefore a systematic investigation of the Russian government bond yields' behavior with respect to factor analysis is relevant and arouses interest.

Thus, the main objective of the research provided is to analyze how fundamental macroeconomic factors, expectations and changes in the monetary policy, changes in the external markets, and features of the current economic and political situation affect the yields of the GKO-OFZ market in 2003-2009, as well as to determine factors to which interest rates respond mostly. To achieve this goal we, firstly, analyze the development of Russian public debt market and outline its main structural features in order to identify and examine a list of potential factors influencing the dynamics of the nominal yield, paying attention to theoretical assumptions and empirical literature. Secondly, we construct short-and long-term single-factor models of four theoretically grounded determinants, based on regression and cointegration analyses. The findings of the second stage help to identify the most informative variations of basic factors, reflected in the dynamics of nominal yields. Then multiple-factor models are estimated: firstly, optimal model specifications based on theoretical fundamentals are identified, and given that, the contribution of the whole range of factors is assessed. As a result of such comprehensive approach we can not only derive the most significant driving determinants of

¹ U.S. Treasury bond yields' analysis dominates here as international benchmark interest rates, as well as special emphasis is given to theoretical models of term structure and yield spreads analysis of EU;

interest rates, but also analyze the impact of weaker factors, understand the specificity of the Russian government bond yields' formation.

Therefore we draw conclusions concerning close relationship between sovereign debt market and money market, the importance of foreign exchange risk and political and economic events for the dynamics of government bond yields, varying for different maturities. Low significance of inflation and the lack of actual impact of external factors and foreign bond market's yield on Russian yields are notable findings against various results on the US and EU markets.

The paper is organized as follows. In Part 2 a brief review of related literature on government bond yields is presented. In Part 3 a qualitative analysis of the situation on the GKO-OFZ market during 2003-2009 is carried out. In Part 4 the potential determinants of bond yields are characterized and a range of relevant factors is chosen for further research. Part 5 describes the data used in the empirical analysis. Part 6 explains the empirical methodology and defines basic econometric methods used in the study, whereas Part 7 presents the results of empirical assessments of bond yields' sensitivity to factors with more precise model specifications estimated for each stage of the analysis. The final part is summarizing and discussing the results of the research.

2. Related literature review

One of the main theoretical statements given in modern books on the market of fixed income (Choudhry, 2001, Fabozzi, 2007) is the assumption that the required rate of return on government bonds is a function of the discount rate. Among other factors the ratio of government budget deficit and public debt to nominal GDP, economic policy, as well as supply and demand on the government bond market are stated.

Empirical papers concerning the return on government securities have certain specifics and can be roughly divided into the following groups: studies with focus on modelling the term structure of interest rates based on a few orthogonal latent factors (Litterman and Scheinkman, 1991, Diebold and Li, 2006, Vicente and Tabak, 2008, etc.), latent factors and macroeconomic changes (Diebold et al, 2005, Ang and Piazzesi, 2003, Evans and Marshall, 2007, Chi-Sang, Ip-Wingyu, 2008, Sekkel, R.M. et al, 2010); studies on testing of theoretical hypotheses, such as inflationary expectations impact (Atkins, 1989, Payne и Ewing, 1997, Granville и Mallick, 2004, Liu, 2006, Österholm, 2009, etc.), dependence of interest rates under study on foreign debt markets yields, based on the theory of interest rate parity (mainly in Asian countries, Inoguchi, 2007 and others); analyses of yield spreads (mainly in the euro area, IMF, 2003, Ferucci, 2003, Orlovski, 2005, Manganelli S., Wolswijk G., 2007, Ebner, 2009, etc.); researches of yield of government bonds of exact maturity (Bandholz et al, 2009, Mehra, 1994, 1995).

Hereinafter the studies of government bonds yield movements and its sensitivity to various factors, which are the most meaningful for our research, would be briefly reviewed.

Thus, concerning interdependencies between internal and foreign interest rates, Inoguchi (2007) runs a regression equation with non-stationary but cointegrated parameters on daily basis and finds significant correlation between the main markets of East Asia (Hong Kong, Singapore, Thailand) and the U.S. Treasury market with an attempt to test also the variance of yields. On the contrary, one of the studies (Cheung Yin-Wong et al, 2008) of the Chinese market concludes that U.S. Treasuries rates' dynamics has a very low impact on short-term rates in China.

There are a lot of studies on testing the impact of inflation and its expectations on nominal interest rates, most of which employ cointegration techniques as the Fisher hypotheses is a long-run equilibrium condition. Granville и Mallick (2004), investigating a relationship between inflation and 3-month T-bills yield over a period of 1900-2000, confirm a full Fisher effect²; Österholm (2009) examines the reflection of current inflation in Norwegian nominal interest rates using annual data since 1850 over a long period of time and confirms the hypothesis on assumption of integration of inflation and yield of the same order. Interestingly, in China the influence of inflation is not verified in short-run, and in the long-run the full Fisher effect is not found (Liu et al, 2006). Rare studies of other emerging markets (Argentina, India, Thailand) also do not reveal long-term relationship between bond yields and current inflation, what was explained as a result of a non-constant real interest rate³.

A wide range of studies deals with the analysis of yield spread movements. In one of the recent papers (Ebner, 2009), the author runs single-country regressions to identify the sensitivity of interest rate spreads to market, fundamental and event indicators. He finds a strong evidence for the significance of market factors (inflation, volatility, discount rate and liquidity) and for much weaker influence of macroeconomic factors, explaining nearly 20-25% of spread's variation. Ferucci (2003) investigates yield spreads of 23 countries and finds that the spread moves with changes in fundamentals and also that market factors and additional information such as political risk and quality of institutes play a rather important role. Results of Orlovski (2005) indicate the importance of changes in inflation, exchange rate, discount rate and the yield of a benchmark 10-year German bond for Poland, Czech Republic and Hungary. The authors of a brief regression analysis of yields on the same markets from IMF (IMF, 2003) find evidence for the main impact of macroeconomic factors and no effect of German bond yields.

² In case of the Fisher effect presence, a current change in inflation will lead to a one-for-one change in the nominal interest rate in the long-run;

³ It contradicts the Fisher hypothesis assumptions;

The study of Joseph E. Gagnon (2009) covers the analysis of sharp changes in exchange rate and consequent changes in interest rate dynamics, based on historical yields of 20 countries. Changes in CPI, output growth and previous bond yield appear to be the most important drivers of current yield movements.

The following line of studies considers factor analysis of government bond yields of particular maturities which is based on cointegration analysis. Such models allow to estimate changes in bond yields both in short- and long-run and to identify the possibility of bringing to state of long-term equilibrium.

In the researches of Mehra (1994, 1995) the dynamics of long-term (30-year) and short-term (1-year) bond yields are investigated. Using quarterly data from 1955 to 1994 the author constructs short-run and long-run models driven by expected inflation (current and estimated), real budget deficit, real GDP growth and real Fed Funds rate as a factor of monetary policy. The findings indicate that inflation is the most important determinant of movements in the long-run (real deficit is of very low impact); changes in Fed Funds rate contribute to substantial changes in short-run. Short-run dynamics of 1-year yield reflects a higher contribution of the monetary factor and real GDP growth, what can be the evidence for the short end of the term structure to be dominated by actions of the monetary policy and the state of economy.

The paper of Bandholz et al (2009) deals with the problem of explanation of unusually low yields of long-term Treasuries during 1986-2006. The authors assume the impossibility of determining the yields only by internal fundamental factors (inflation, monetary policy, the business cycle) and additionally consider more structural factors (foreign holdings of US Treasuries). As a result 32% of the bond yield's variation is explained by their model in the short-run, moreover, as in Mehra (1995), no effect of fiscal changes is revealed.

Finally, we will briefly focus on Russian research works, where the studies of Drobyshevsky (1999, 2009), conducted on GKO-OFZ market's yield before crisis of 1998 and afterwards, are worth noting. The researcher outlines the peculiarities of the Russian market of government bonds and investigates the individual impact of macroeconomic parameters, monetary changes and fiscal policy on changes in nominal and real interest rates. Consequently, the results of the first study revealed no substantial effect of changes in monetary and budget policy on the government securities' yield, but showed strong evidence for the driving force of inflationary expectations and exchange rate. A more recent work demonstrates similar method and results.

Therefore, we have considered a wide range of research areas concerning empirical analysis of sensitivity to economic factors and determinants of nominal government bond yields. Aiming to conduct an extensive analysis of determinants of the government bond yields in Russia these findings would be taken into account in the following study.

3. The outline of the Russian government securities market

This section deals with the most substantial features of the GKO-OFZ market development and grounds for yield formation (especially after 2002), as well as outlines main economic factors and events which, according to current circumstances, could react on nominal yields.

The Russian government securities market has a nearly 17-year history, if originating from the first auction in May 1993, where the first 3-month bills (GKO) were allocated in the amount of 0.88 million. During this time the market has experienced different periods of rapid growth and sharp declines, being almost "reborn" again in mid-1999.

Thus, the dynamic growth of GKO very quickly led to the fact that short-term bonds became an essential component of budget deficit financing: GKO yields ranged from 30% to 200%. After the crisis of 1998 in the process of debt restructuring qualitative changes happened to the market, more medium- and long-term bonds appeared, but investors' expectations still varied depending on the unstable economic situation. In the early 2000s the bond market started to slightly develop, as a gradual resumption of the lost confidence in government instruments revived the market, turnover increased and a slightly decreasing trend was noticed in rates of return. From then on, growing market transparency, introduction of demanded long-term instruments with debt depreciation (OFZ), auctions of direct repo against the Bank of Russia, commission reduction as well as favorable macroeconomic conditions, excess ruble liquidity and the efforts of the ministry of Finance and the Bank of Russia suggest that in 2002 the GKO-OFZ market regained the status of a benchmark of interest rates, although it had low capacity and activity of trades. But since that time the market evolved in the circumstances of constant state budget surplus, lack of serious need for borrowing on the domestic market, relatively stable decrease of nominal yield and the growth of debt maturity.

New ruble public debt was issued mainly for pension funds allocation and partial repayment of external debt. Accordingly, the Russian domestic debt for the period from January 2003 to December 2009 increased by 2,8 times, marketable debt increased by 2.43 times over the same period. Government debt market capacity, declining till the end of 2008, accounted for 3.43%, what is assumed as a very low value. By the end of 2009 the capacity of the debt market tended to rise due post-crisis decline in GDP growth and increase in the nominal volume of domestic loans⁴.

It should be noted that Russian nominal foreign debt decreased by more than three times over 2003-2009 (to 31.3 billion dollars), and that most significant repayments of external loans occurred in 2005 and 2006. During these periods long-term debt to the members of the Paris

⁴ See Table A1 in Appendix A;

Club was virtually eliminated, which, in its turn, reduced the debt burden and became one of the reasons for the decrease in medium-and long-term yields of the ruble debt segment.

The market is notable for small average daily turnover; the trading dynamics is characterized by sharp spikes, which confirms the thesis of low market liquidity after 1998, as well as high volatility of the considered indicators. Liquidity of government securities market is still very low, due to general characteristics of the market: «negative real yield of OFZ, low coupon rates on most traded issues, a majority of market participants, adhering to the strategy of "buy and hold to maturity"⁵». This reduces the possibility of the Ministry of Finance to borrow on the domestic market easily.

Concerning market liquidity, it is necessary to mention the structure of core investors in government bonds over the observable period. It is represented mostly by state banks (Sberbank, VTB), MC Vnesheconombank, the Russian Pension Fund, the Bank of Russia and large commercial banks. More than 75% of market value is concentrated within this limited number of participants, i.e. in 2006 Vnesheconombank, Sberbank and the Russian Pension Fund had nearly 48% of bonds outstanding. Pension savings are invested in a government bonds, reducing their liquidity (in 2008 the Pension Fund's portfolio consisted of 93% of government financial instruments). On the other hand, banks do not have a strong demand for long-term bonds because of a limited share of long-term deposits. What is more, investments in OFZ by the largest banks are, to a certain extent, induced, as the banks need to allocate liquidity into instruments with high credit quality. Insurance companies and investment funds, which make up the largest share in bond markets abroad, are practically not present in the Russian market, as well as individual investors, pursuing speculative interests.

As far as the nonresidents are concerned, they were forbidden to bring new capital to the Russian public debt market until 2004, when further regulations established standards of funds reservation with the Bank of Russia (from 20% to 7,5% nowadays). As a consequence, the share of nonresidents in the market decreased in 2003 and accounted for 3,3%⁶, and «remained extremely low»⁷ in 2005. The important stage of currency liberalization in autumn 2006 considered an increase in the share of foreign investors and capital inflow, but they still treat the Russian financial market with distrust. After the crisis in world financial markets in 2008, when searching for the least risky refuge investors withdrew capital from most emerging markets, the share of foreign investors on the government bond market in Russia remained negligible. But

⁵ According to «Financial market report», the Research and information Department of the Bank of Russia , first half of 2009, №2 (67);

⁶ According to Herald of the Bank of Russia, №65 (717)// www.cbr.ru;

⁷ According to Herald of the Bank of Russia, №17 (887)// www.cbr.ru;

already in 2009 nonresidents got a 1,7% share of the nominal value of bonds outstanding, what is 4,5 times more, referring to a growing attraction of the market for investors from abroad.

Further we represent the most substantial results of the analysis of government bond market's characteristics while recently developing:

1) state budget surplus (except for changes in 2009) and the cautious policy of Ministry of Finance and the Bank of Russia with the intention of the GKO-OFZ market recovery have reduced the need for domestic loans, which resulted in low public debt market capacity and little growth of nominal debt;

2) gradual acknowledgment of Russian creditworthiness by international rating agencies (up to a period of the latter crisis);

3) the structure of investors in the GKO-OFZ market is mainly represented by large public investors and banks (with a slowly growing share of non-banks); foreign capital is virtually not invested in ruble-denominated bonds over the period from 2003 to 2009;

4) maintained low level of interest rates and consequent negative real return on bonds since 2002 limit investors' interest in "riskless" ruble instruments;

5) low and heterogeneous liquidity of the public debt market instruments, resulting from the narrow structure of investors, negative real yields and low market capacity, weakens the market reaction to external changes.

Additionally, from the results of the detailed analysis of the GKO-OFZ market situation, based on fixed income analysts' reports⁸, it is concluded that the following factors and events can hypothetically influence the rate of return on the Russian government bond market: 1) rate of change in CPI relative to the previous period and uncertainty regarding inflation, 2) changes in interbank interest rates and balances on correspondent accounts with the Bank of Russia (close relationship with the money market is due to the base of investors), 3) expected inflationary implications of bank liquidity expansion, 4) change in exchange rate, 5) change in energy resource prices, 6) decisions concerning Russian external debt repayments (2005-2006), political claims, 7) external bond markets' state.

The findings achieved are used in the following empirical study at selecting potential drivers of yields in the GKO-OFZ market, correct models constructing and interpretation of results.

4. Selection of factors under study

⁸ The main data base for the analysis is taken from the analytical section "Monthly reviews of the government securities market performance on the MICEX" over the observable period; full text of this subsection is available on request;

After a brief analysis of the situation on the Russian government bonds market during 2003-2009 and a literature review we are familiar with a rather wide range of factors, which can be reflected in nominal rates on government bonds. As there is little guidance in the literature on which variables are essential to include in the bond yield modelling, in Table 1 we characterize each factor and show main principles of selecting a more specific set of potential fundamental and market determinants of the GKO-OFZ market yield.

Table 1.

Factor	Features of influence	Hypothesized impact on the yield of the GKO-OFZ market
GDP growth	Subject to successful development of production and the growth of wealth, investors have no doubt in the successful development of the market and reduction of risks, thereby agree to lower rates.	<u>Reverse impact</u>
Budget deficit	A high budget deficit induces the government to raise more funds, and therefore the higher are the yields of government bonds.	<u>No effect</u> (due to annual budget surplus (except 2009) and low GKO-OFZ market capacity till 2009)
Real public debt growth	Market participants estimate the increase of risks of possible default of the debtor (the government) in case of a dynamic growth of debt with increasing capacity of the domestic debt market.	<u>Low direct impact</u> (Due to low market capacity)
Inflation (y/y, m/m, expectations of changes in CPI for several months ahead)	Investors are likely to claim compensation for depreciation of assets (par value) because of expected inflation. Also investors may expect future monetary tightening (raising short-term rates) with a view of controlling and reduction of high inflation. Theoretical ground - the hypothesis of Fisher.	<u>Direct impact</u>
Exchange rate movements (appreciation)	Currency appreciations may be expected to lower inflationary expectations and improve the state balance, thereby leading to a positive effect on yields of bonds of all maturities. Decrease of foreign exchange risk makes investments in OFZ more profitable for foreign and Russian investors, strengthens their confidence in the economy.	<u>Direct impact</u>
Situation in the Treasury bonds market (USA)	Theoretical ground: the theory of interest rate parity, whereby in an open economy, interest rates in different countries differ in currency depreciation and country risks. Until 1997, the correlation between the GKO-OFZ market and U.S. Treasuries was much higher than in recent years. In addition, very low proportion of non-residents in the GKO-OFZ market limits the impact of foreign debt markets on the sovereign debt market of Russia. But the dynamics of such a risk-free benchmark as the U.S. Treasuries, should, to some extent, determine risks of investing in objectively more risky developing economies.	<u>Low direct impact</u>
Interbank interest rate (IIR)	As an indicator of alternative investments in the money market and a guideline of monetary policy actions, interbank rate has the greatest impact on the rate of return of short- and medium-term bonds. Growth of IIR increases the yield against a decline in the level of bank liquidity and the need to "get" ruble liquidity by selling government securities.	<u>Direct impact</u>
Banks' balances on correspondent accounts with the Bank of Russia	Indicator of excess bank liquidity	<u>Reverse impact</u>

M2	Indicator of the general level of liquidity. Injection of cash liquidity in the financial system leads to an increase in demand for financial assets (demand for bonds is increasing as a means of excess liquidity allocation). It causes a drop in nominal interest rates in short-run; in the medium-term period it increases prices and results in a slowdown of the reduction of rates. Theoretical ground - the effect of the expansion of liquidity.	Short-term: <u>Reverse impact</u> Middle-term: <u>Direct impact</u>
Official discount rate	Reflection of the strategy of monetary policy (an effect mainly on the U.S. market).	<u>No effect</u> (We assume that in emerging markets a discount rate is not a key indicator of changes and trends in the financial sector, but is derived from the economic processes)
The Bank of Russia REPO minimum interest rate	The importance of changes in the average cost of funding. On the balance sheet of a commercial organization (the bank) government bonds are recognized as the most liquid assets, virtually not generating income. According to market transactions' practice, low-yield government bonds are used as financial instruments for improving return on investments and attracting liquidity by repeating repo transactions. Therefore, and this is confirmed by a growing capacity of the REPO market segment, average cost of banks' funding in the money market substantially determines the pricing in the government bonds market. Costs of repo transactions with the portfolio of government bonds are limited to the level just above the REPO minimum interest rate. In turn, its growth leads to a proportional increase in required return on instruments used in transaction, since in case of a possible upturn of interbank and repo rates the average cost of funding exceeds the average yield of bonds, making operations with them unprofitable.	<u>Direct impact</u>
Oil Price	Impact on the international economic situation. Raising consumer goods prices, improving the performance of exporting countries, reviewing the balance of payments support GKO-OFZ market. On the other hand, because of high oil prices, currency earnings increase and, consequently, the volume of liquidity grows, which over time leads to an increase in inflation and growth of interest rates.	<u>Reverse impact</u>
International reserves growth	The volume of international reserves demonstrates stability of the economy, its resistance to currency shocks, and shows the potential for strengthening of ruble and financial system maintenance. Reduction of international reserves causes a disturbance among investors, negatively adjusting their expectations.	<u>Reverse impact</u>
Political/economic events/claims	Affecting yields of government bonds owing to increase or decrease in political and country risks.	Increase of risks – <u>direct impact</u> Decrease of risks – <u>reverse impact</u>
Market information	Actual crisis situation in financial markets influences investors' behavior: yields are moving under pressure of more risk-averse, uncertain about future investors, which is reflected in required additional risk premium in rates of practically risk-free instruments.	<u>Direct impact</u>

As a result, four categories of potential determinants of bond yields are sorted out, notably: (*macroeconomic*) real GDP growth rate, rate of change of the CPI, growth rate of domestic debt, change in exchange rate of national currency; (*monetary*) interbank interest rate, change in balances on correspondent accounts with the Bank of Russia, change in M2, minimum REPO

rate; (*international*) oil inflation, change in international reserves, foreign debt market interest rate (US Treasuries); (*event*) crisis in 2008-2009, external debt repayment in 2005 and 2006, reelection of V.V. Putin as a president of Russia in March 2004, arrest of the head of Yukos in 2003.

5. Data and definition of variables

In the present study we consider yields of the zero-coupon yield curve, which has been estimated on MICEX since 2003, as a key indicator of interest rates on the government bond market⁹. Zero-coupon yields are suitable for outlining the peculiarities of yields of different maturities and carrying out adequate comparative analysis, as well as coupon effect eliminating, which is inherent in traditional yield to maturity. For the purpose of explanation of fluctuations along the entire yield curve, bond yields of 5 maturities are analyzed separately: 1-year (SR), 3-year, 5-year (MR) and 10-year, 15-year (LR). Fig.1. depicts the dynamics of the analyzed government bond yields.

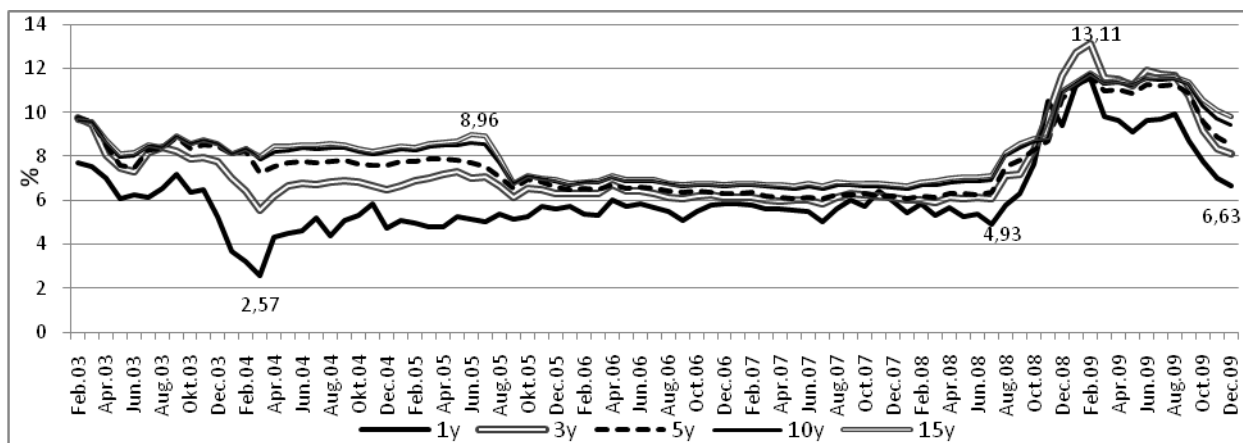


Fig. 1. Government bond yields

The period covered by the analysis starts from Feb.2003 and goes till Dec.2009, owing to the availability of zero-coupon yield data and on the assumption that after 2002 the GKO-OFZ market has to a certain extent recovered its status as a benchmark of market interest rates. Over the observable period the average yield curve is rather flat, with a sharp upturn till a 3-year term to maturity; a crisis subperiod differs much from the yields' general dynamics¹⁰.

All the data in study (either dependent or explanatory variables) are on monthly basis (end of month)¹¹; the original sample has 83 observations. All variables are expressed as changes in

⁹ This indicator is estimated on basis of Nelson–Siegel model with liquidity adjustments according to Russian specific features, available on www.micex.ru;

¹⁰ See descriptive statistics in Appendix A;

¹¹ It is conditional on, firstly, using macrofactors in the analysis, which are computable on quarterly and monthly basis; secondly, end of month data helps to avoid excess autocorrelation in the residuals and incorporates all the information of the respective month;

percents or in percentage points. Table 2¹² presents detailed description of parameters and their variations (i.e. for inflation), which are analyzed in the following empirical research.

Table 2.

Description of the parameter	Designation	Description of the parameter	Designation
Yield of <i>N</i> -th term to maturity, at the end of the month, pct (difference)	(Δ)YEARN	Brent spot-price growth, %	Δ BRENTREL
Rate of real GDP growth ¹³ , %	Δ GDP_REAL	1 (2)-month Brent futures contracts growth,%	Δ BRENTFUT_1(2)m
Rate of real public debt growth, %	Δ DEBT_REAL	Interbank interest rate, pct (diff.)	(Δ)MIACR_1M
Current inflation (difference), pct	(Δ)CPIYY	Minimum REPO rate, pct (diff.)	(Δ)REPOMIN
Geometric mean expected inflation for <i>n</i> months ahead (difference), pct	(Δ)CPIYY_0_n	Rate of money supply growth (M2), %	Δ M2_RATE
Geometric mean inflation for the past <i>m</i> months, %	CPIYY_m_0	Problems with Yukos (07.2003 =1)	DBLIP_03 ¹⁴
Exchange rate growth (based on the official exchange rate), %	Δ USD	Presidential election (reelection of Putin, 03. 2004 =1)	DBLIP_04
Geometric mean expected exchange rate growth for <i>n</i> months ahead, %	Δ USD0_n	Repayment of external long-term debt (09.2005 =1)	DBLIP_05
International reserves growth, %	Δ RESERVES	Expectations of external long-term debt repayment (08.2005=1)	DBLIP_05_EXP
10-year U.S. Treasury bond yield (difference)	(Δ)UST10Y	Repayment of external long-term debt (09.2006 =1)	DBLIP_06
Growth of balances on correspondent accounts with the Bank of Russia, %	Δ CORR_RATE	Crisis situation (2008-2009) (= 1 in case of a bond yield of <i>N</i> -th term to maturity exceeds average yield of the crisis period)	DUMN
Geometric mean rate of M2 growth for 3 months taken 6 months ago ¹⁵ (difference) – as a factor of inflationary implications of money supply growth	(Δ)DM2_4_7		

One of the problems in estimating factor models is that anticipated inflation and exchange rates are unobservable variables. Therefore in some of the models the perfect foresight hypothesis is accepted, reflecting the rationality of economic agents, which allows using actual future values of inflation and exchange rates as expectations. Also current values are used as proxies.

6. Empirical methodology

1) The first stage of the empirical research is preliminary analysis of data with respect to two issues: correlation between bond yields of 5 maturities and their hypothesized determinants and stationarity assumption of the examined time series. Firstly, correlation analysis helps to choose the most relevant variations of factors for further modelling as well as to provide first results

¹² Data is taken from the Bank of Russia (cbr.ru), Ministry of Finance (minfin.ru), Prime-Tass Agency (prime-tass.ru), US department of the Treasury (ustreas.gov), Reuters Database.

¹³ Growth rates of factors are measured as $\left(\frac{P_t}{P_{t-1}} - 1\right) * 100\%$;

¹⁴ The most important political and economic events are taken into account and included in the analysis as blip dummy-variables;

¹⁵ Measured as $dm2(n-k) = \left(\frac{M2_{t-n}}{M2_{t-k}}\right)^{\frac{1}{n-k}} - 1$ according to *Drobyshevsky et al (1999)*;

regarding the direction of their impact on yields. Secondly, special attention should be paid to the fact that most financial and economic time series are not stationary, and that running a regression with nonstationary variables may cause estimates of a spurious regression with high R^2 and low t-statistics of coefficients. Therefore in every case unit-root Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test are applied, complemented by results of the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) test, which checks an alternative hypothesis of stationarity in series and is used when the first two tests are in disagreement. The conclusion is drawn on the outcome of all three tests.

In addition, we should outline that for financial time series the alternation of high and low volatility periods is typical, according to relative stability and uncertainty in the market. As a consequence, a problem of conditional heteroscedasticity in residuals may arise¹⁶. Thus, ARCH-LM test with one lag is carried out where necessary at significance value of 5% as a most common case. If the test shows heteroscedasticity, an appropriate for many financial series GARCH (1,1) specification is assessed¹⁷.

2) At the second stage of empirical estimation we examine the individual impact of the four fundamental factors, whose influence is based on the theoretical assumptions: inflation, exchange rate, the rate of return on the external bond market and money supply.

Subject to nonstationary time series, both short-term relationship between the bond market and factor variables, based on the consideration of variables in first differences, and long-term dynamics of yields are interesting to investigate. Cointegration analysis is thereby an ideal method, identifying, if existing, a stationary linear combination of nonstationary variables, which in its turn reflects long-term relationship between yields and examined factors, their convergence to long-term equilibrium. Here we use a 2-step Engle and Granger (1987) procedure, which tests a unit root in the residuals of a first-stage regression ($ECT_t = YearN_t - \alpha - \beta * P_t$, where P is a non-stationary series of explanatory variable) and a more powerful Johansen (1991) test, based on VAR-model. Resulting from cointegration analysis short-term and long-term dynamics are separated: deviations from long-term equilibrium are, to some extent, adjusted by «error-correction mechanism» in the short-term regression. Formally error-correction model is as follows:

$\Delta y_t = \alpha * \Delta x_t + \gamma * (y_{t-1} - \beta * x_{t-1}) + \varepsilon_t$, where Δy and Δx are stationary first differences of explained and explanatory variables (short-term impact), and in parenthesis there

¹⁶ In our research low probability of conditional variation of residuals is assumed, owing to the fact that we consider series of low frequency (month), nevertheless the test is necessary to be conducted;

¹⁷ The results of tests are not presented;

is an error of stationary equilibrium cointegrating equation of the previous period (long-term disbalance with x -factor), further denoted as ECT_{t-1} .

The long-term impact of inflation is considered according to the Fisher hypothesis $asi_t = r_t + \gamma\pi_t^e + \varepsilon_t$, the impact of the exchange rate and external interest rate is estimated under the assumption of the uncovered interest rate parity. The liquidity effect of money supply expansion is analyzed by estimation of VEC-model, which includes not only lagged changes of yields and growth of M2, but also simultaneous changes in current inflation.

3) At the third stage of empirical study a joint influence of basic theoretical determinants is analyzed, where more relevant factors are selected due to previous findings. According to Mehra (1995), in the long-run economic policy can affect the nominal interest rate mainly through inflation targeting, and we assume this effect of inflation on interest rates as fundamental and exceptional. Thus, in case the Fisher hypothesis works in our market, an error-correction term of long-term disequilibrium with inflation would be included into the short-term model in first differences. As a result of this step the most efficient model specifications of yield generation are outlined.

All the estimated models are tested for autocorrelation and heteroscedasticity (mostly by Breusch-Godfrey Serial Correlation LM test, PACF correlograms' analysis and White test). It is also important to mention that when assessing regressions with only one or two factors autocorrelation is more likely because the effect of other potential economic changes is not taken into account. Thus in case of mentioned nonlinearities, we mostly use robust standard errors of Newey–West¹⁸. What is more, optimal regression equations, identifying the effect of most relevant factors, are chosen according to the explanatory power of the estimated model, information criteria of Akaike and Schwarz, standard error of regression and other properties.

4) The final step of econometric modelling comprises all the findings, achieved at earlier stages of the study. Thus, explanatory variables are included in the regression equations in accordance with previously derived findings regarding sensitivity to inflationary expectations, exchange rate risks and correlation analysis as well. The following general models are estimated:

$\Delta yearN_t = \alpha + \sum_{i=1}^k \beta_i x_{ti} + \sum_{i=k+1}^K \beta_i x'_{ti} + \varepsilon_t$, where x'_i are event dummy variables, and x_i are other 3 categories of examined factors, all described in Part 5. It is worth mentioning that if a «good» model specification based on theoretical fundamentals is notable for a significant impact of an error-correction term of long-term non-balance with inflation, this effect is also considered in general models. In conclusion a brief analysis of robustness is carried out, based on Chow tests and CUSUM/CUSUMSQ tests.

¹⁸ In several models it is more efficient to add required AR(p) parameters (Cochrane-Orcutt procedure is run);

After multiple-factor models are properly constructed and estimated, the main driving factors, whose complex impact on the government bond rates of return appears to be the most substantial, are identified. Taking into account the difficulty of modelling changes of financial indicators, Russian specifics and the results of empirical research works, considered in Part 2, we assume the level of 40-70% of explained yield's variation as satisfactory (by R^2 -adjusted).

Necessary details of model specifications and included variables are given in the course of the empirical research.

7. Results of government bond yields modelling in the Russian market

Starting from detecting the most informative factors, characterizing the behavior of the government bond yields, we turn to the quantitative analysis of their individual and joint effect on interest rates' movements.

7.1. Preliminary analysis of data

The assessment of pair correlation between zero-coupon bond yields and different variations of macroeconomic, monetary and international factors provide us with the preliminary results regarding their joint dynamics. Thus, substantial potential relationship is revealed between interest rates and current inflation, inflationary expectations for 1 and 2 months ahead (correlation coefficients decrease with time horizon), current national currency depreciation/appreciation against the U.S. dollar, expected exchange rate growth up to 3 months ahead, M2 growth rate, 1-month interbank rate (MIACR), minimum REPO rate, international reserves growth rate as well as the growth of prices of 2-month Brent futures, which we interpreted as expectations of oil inflation. Growth of real public debt and real GDP are notable for low and insignificant correlation with bond yields, what would be taken into account when estimating multiple-factor regressions. Other tested variations of factors and their expectations (inflation, monetary factors), potentially responsible for interest rate movements, are eliminated from further analysis as being less informative. We summarize some of correlation analysis results in Table B1 (see Appendix B). Correlations of returns with all examined factors confirm presupposed direction of influence.

Verifying of the stationarity assumption for the data in levels leads to the following conclusion: 1) government bond yields of all the considered maturities have a unit root at 5% value of significance; 2) all the time series of inflation, 10-year US Treasury bond yield, minimum REPO rate and rate of M2 growth for 3 months taken 6 months ago are assumed nonstationary according to the majority of applied unit-root tests. Table B2 (see Appendix B) presents some of unit root test results.

Consequently, practically all the models (except for cointegrating regressions) include the dependent variable as $\Delta yearN_t = Nyear_t - Nyear_{t-1}$ and other nonstationary variables in stationary first differences of I(1).

7.2. Individual impact of basic theoretically grounded factors on yields

This section of the study presents the main findings of the individual effects of inflationary expectations, exchange rate growth, changes in the foreign government bond yield and expansion of money supply on Russian zero-coupon yield according to methods and theory, briefly described in Part 6.

7.2.1. Impact of changes in CPI

From the correlation analysis we reveal four most informative factors of inflationary expectations which can be taken into account by investors: current inflation, averaged for the past 12 months inflation and expectations of the rate of change of the CPI for one and two months ahead (it is worth noting that correlation coefficients are surprisingly low). Furthermore, given the same order of integration between time series of yields and inflationary expectations, a cointegration analysis is applied to model the long term relationship, that is, to check the Fisher hypothesis on the Russian market. Engle-Granger procedure and Johansen test constitute a weak (without a constant term) long-term relation between inflation, expected for one and two months ahead, and medium- and long-term interest rates, as well as between short-term segment of the yield curve and current rate of change of the CPI. This implies that the Fisher hypothesis, to some extent, holds in the market, although nominal yields do not adjust on a one-for-one basis with the change in expected inflation, in other words the full Fisher effect does not exist.

Consider a stricter error-correction model in the following form, which tests a short-term impact of annual inflation on yields and may confirm cointegration tests' results:

$\Delta yearN_t = c + \alpha * \Delta cpiyy(_0_n_t) + \gamma * ECTN_{t-1} + \varepsilon_t$, where $ECTN_{t-1}$ – is a correspondent balancing term in case of identified cointegration between a particular investigated time series of inflation and bond yield of N years to maturity. In Table B3 (see Appendix B) the estimates of the single-factor models verify cointegration relationships established above (error-correction coefficients are negative and significant with a small magnitude, implying a slow response rate to non-balance) and indicate that in short-run government bond yields reflect only changes of annual inflation, averaged for the past 12 months. It is also evident that the sensitivity of interest rates to inflation decreases with increasing maturity.

Summing up, we conclude that current inflation and its expectations exert a low influence on determining a long-term trend in government bond yields of examined maturities. One of

explanations may concern the discrepancy between investors' inflationary expectations and actual values which are used in our modelling. On the other hand, these findings regarding current and expected inflation can be interpreted as ineffectiveness of monetary policy in short horizons.

7.2.2. Impact of money supply increase

As earlier was stated we surmise a negative impact of liquidity growth on mainly short-term interest rates and also a slight increase in rates in the medium term period. For the purpose of detecting the effect of money supply expansion on bond yields the following Vector Error Correction Model is applied to data, as we wish to consider simultaneous changes in inflation:

$$\begin{pmatrix} DyearN_t \\ Dcpi_t \\ DM2_t \end{pmatrix} = \begin{pmatrix} \Phi_p(DyearN_{t-p}) & \Phi_p(Dcpi_{t-p}) & \Phi_p(DM2_{t-p}) \\ \Phi_p(DyearN_{t-p}) & \Phi_p(Dcpi_{t-p}) & \Phi_p(DM2_{t-p}) \\ \Phi_p(DyearN_{t-p}) & \Phi_p(Dcpi_{t-p}) & \Phi_p(DM2_{t-p}) \end{pmatrix} * \begin{pmatrix} a_{year} & b_{year} & d_{year} \\ a_{cpi} & b_{cpi} & d_{cpi} \\ a_M & b_M & d_M \end{pmatrix} + \begin{pmatrix} \gamma_1 * CE(cpi) \\ \gamma_2 * CE(year_N) \\ \gamma_3 * CE(M2_t) \end{pmatrix} + \begin{pmatrix} \varepsilon_t \\ \mu_t \\ \delta_t \end{pmatrix},$$

where CE – cointegrating equations from the Johansen test; *included variables* – differences of yield, current inflation and money supply; a, b, d – vectors of estimated coefficients at lagged variables; ε, μ, δ – random errors; $p=q-1$ – lags, (q – optimal lag length tested in VAR-model).

In whole the observed response functions of changes in nominal interest rates to a positive shock of M2 measured as impulse to one standard deviation of the residuals (an increase in M2 growth rates) show the decline in interest rates for all maturities. Slumps of yields occur during the first four months for bonds of one and three years to maturity, for yields of bonds with longer maturities a much less substantial decline over three months is evident. These results demonstrate the effect of liquidity after the increase of money in the economy (Fig.2¹⁹). Then short-term yields weaken their decline up to 6-7 months after the injection of liquidity, which is practically insignificant for longer interest rates.

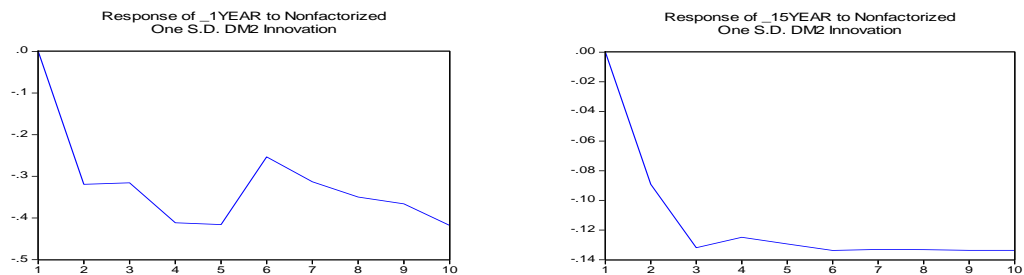


Fig. 2. Impulse response functions of yields (1 and 15 years to maturity) to money supply increase

As a consequence, we conclude that inflationary implications of money supply expansion are practically not taken into account when explaining the current level of medium-and long-term interest rates, reflecting an increase in yields only in the short-term segment of the yield curve. From response functions we observe expected evidence for a seriously weaker liquidity expansion effect the longer the maturity is.

¹⁹ Response functions for yields of 3, 5 and 10 years to maturity are presented in Appendix B;

7.2.3. Impact of changes in exchange rate

Government bond yields are likely to contain a risk premium for possible depreciation of national currency. Provided a high level of direct relation to changes in the exchange rate and results of the correlation analysis, we consider the following simple single-factor models (without error-correction as all the variables are stationary):

$$\Delta year N_t = \alpha + \beta * \Delta usd0_{n_t} (\Delta usd_t) + \varepsilon_t.$$

Results in almost all cases show a highly significant, but of a small magnitude, dependence of nominal interest rate on current and expected (up to the horizon of 3 months) changes in exchange rate. The impact of exchange rate declines with increasing maturity of bonds as well as the significance of this influence for the dynamics of interest rates. When expectations are taken into account, the current change appears to have the most significant effect on short- and medium-term bond yields, although surprisingly 1-month expectations of changes in exchange rates are more reliable for long-term bonds (see estimates filled with grey in Table 3).

Table 3²⁰. Testing the impact of changes in exchange rate on yields

	$\Delta year1$	$\Delta year3$	$\Delta year5$	$\Delta year10$	$\Delta year15$
ΔUSD	0.117241	0.098903	0.064904	0.054929	0.052129
P-value	(0.0000)	(0.0000)	(0.0181)	(0.0006)	(0.0010)
R² adj.	0.248247	0.306932	0.204815	0.168898	0.150783
$\Delta USD0_1$	0.009567	0.080232*	0.063779*	0.064607*	0.065291*
P-value	(0.7268)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
R² adj.	-0.010756	0.198668	0.198306	0.239597	0.244815
$\Delta USD0_2$	0.079050	0.109431	0.062285	0.062052	0.060330
P-value	(0.0646)	(0.0000)	(0.0004)	(0.0018)	(0.0030)
R² adj.	0.064521	0.241585	0.143796	0.137915	0.129602
$\Delta USD0_3$	0.095250	0.103046	0.057619	0.049382	0.046943
P-value	(0.0456)	(0.0007)	(0.0032)	(0.0048)	(0.0061)
R² adj.	0.070204	0.154133	0.069804	0.057955	0.051130

Notes: Newey-West (HAC) errors are used; *denotes errors in unmodified style

Accordingly, changes in government bond yields of different maturities are partly caused by the expected change in the exchange rate, but the basic dynamics of yields is subject to the exchange rate of the current month. For this reason the most significant factors of current change in the exchange rate and its expected growth rate for the following month (for long-term yields) are to be further analyzed in complex factor models.

7.2.4. Analysis of interaction between Russian and foreign debt markets

Long-term relationship between Russian and US yields' time series is checked out by the presence of cointegration according to Engle-Granger procedure and, given that, regression

²⁰ Low explanatory power of the estimated regressions is due to unaccounted factors;

equations with error-correction terms are further assessed. Then resulting from significance/insignificance of ECTs in estimated models we make conclusions about nominal Russian and foreign yields' convergence in the long-run. The hypothesis of the substantial dependency of the Russian government bond yields from the foreign market (U.S.) is tested by the following EC-model, constructed on the basis of the uncovered interest rate parity:

$\Delta yearN_t = \alpha + \beta * ECTN_{t-1} + \delta * \Delta ust10y_t + \theta * \Delta usd_t + \varepsilon_t$, where $ECTN_{t-1}$ is a stationary correction term, balancing the disequilibrium of the long-run relationship between yields; exchange rate expectations are measured as current values. It must be mentioned that one of the aims of estimating this model on the Russian market is to examine whether volatility in the US nominal yields has any effect on the Russian yields' variance. On account of that, conditional heteroscedasticity in residuals of estimated models is corrected by EGARCH (1,1) specification, in which a parameter of absolute changes in UST10Y is included (denoted as $abs(\Delta ust_{10t})$)²¹.

Turning to the results of estimation (see Table B3 in Appendix B), the only significant (at 1%) factor appear to be a rate of exchange between dollar and ruble, reaffirming the presence of a less substantial influence with increasing maturity of bonds. Moreover, we constitute the lack of influence of foreign interest rates' volatility on the short end of the Russian yield curve.

It is worth mentioning that an inverse relationship with the change in the U.S. 10-year Treasury bond yields (estimated as insignificant) may occur due to the strong impact of the crisis period from July 2008. As previously noted, during the period of general tension and heightened uncertainty in the debt markets investors tried to transfer funds into the most risk-free assets, which U.S. Treasury bonds were mostly considered. This was the reason for a substantial increase in their prices, quite clearly observed in the market since mid-2008 (see Fig.3).

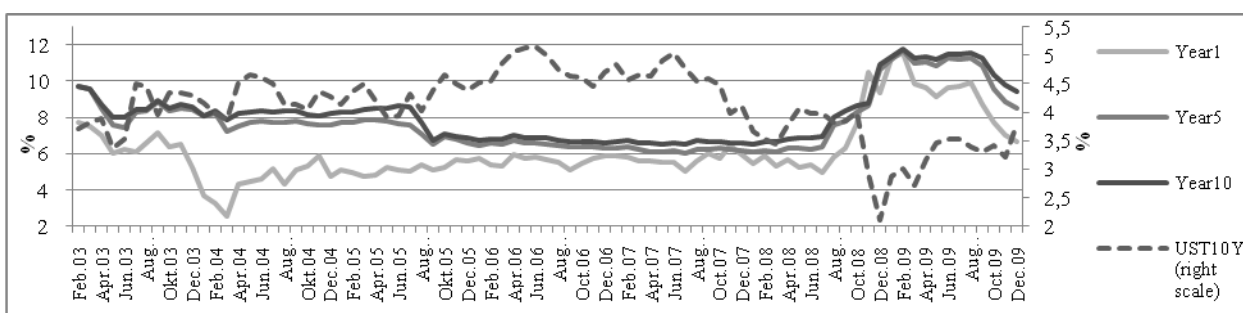


Fig. 3 Yields of short-term, medium-term and long-term government bonds and the yield of UST10Y

However, this fact does not mean that the yields of government bonds in Russia increased due to falling interest rates of the U.S. government securities. The long-term relationship between yields, though confirmed econometrically by the significance of error-correction

²¹ As cluster volatility was observed only for relatively short interest rates (one and three years to maturity), we succeeded in considering the impact of the US bond market volatility only on the short end of the Russian yield curve;

parameters in models, is probably interpreted by the similar considerations as well as the simultaneous influence of other unaccounted determinants of yield. Apart from that the findings concerning the interaction between long-term Russian bonds and UST10Y may provide evidence for a tendency of decreasing country risk in Russia against relatively stable performance of yields on the well-developed bond market of the USA. The following graph presents the trends of joint dynamics of Russian and US interest rates during a period of relative stability (Fig.4).

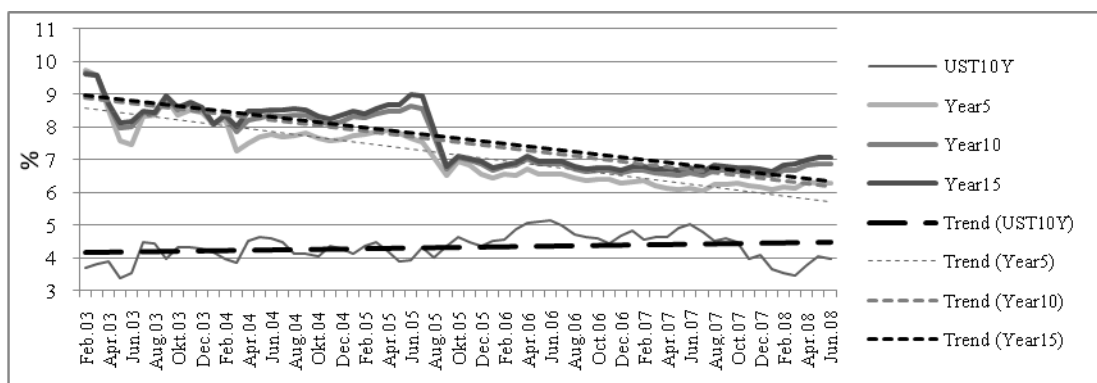


Fig. 4 Dynamics of long-term bond yields in Russia and UST10Y interest rate (Feb.2003 - Jul.2008)

Thus, we are of opinion that there is no (both short- and long-term) actual impact of the US debt market performance on the yields of government bonds in Russia. This conclusion is consistent with the results of earlier conducted analysis of features of the GKO-OFZ market, indicating a low share of non-residents and, therefore, a virtually inessential role of foreign capital in the market.

7.3. Multiple-factor modelling

7.3.1. Modelling of complex influence of basic factors on bond yields

This section aims to establish the complex effect of theoretically based fundamentals, except for foreign interest rates, on nominal yields of Russian government bonds. In addition we analyze a possible impact of inflationary implications caused by money supply growth ($dm2_4_7$). As mentioned before, potential convergence with inflationary expectations is inspected as the only factor of long-term influence. Consequently, we consider the following model specifications, where the factors are chosen according to the previous results:

Model 1 (for N=1-15):

$$DyearN_t = C(1) + C(2) * dcpiy_12_0_t + C(3) * ddm2_4_7_t + C(4) * dm2_t + C(5) * dusd_t + \varepsilon_t$$

Model 2 (for N=3-15):

$$DyearN_t = C(1) + C(2) * dcpiy_0_2_t + C(3) * ddm2_4_7_t + C(4) * dm2_t + C(5) * dusd_t + C(6) * ECTN_cpi_0_2_{t-1} + \varepsilon_t$$

Model 3 (for N=10-15)

$$DyearN_t = C(1) + C(2) * dcpiy_12_0_t + C(3) * ddm2_4_7_t + C(4) * dm2_t + C(5) * dusd0_1_t + \varepsilon_t$$

Model 4 (for N=10-15):

$$DyearN_t = C(1) + C(2) * dcpiyy_0_2_t + C(3) * ddm2_4_7_t + C(4) * dm2_t + C(5) * dusd0_1_t + C(6) * ECTN_cpi_0_2_{t-1} + \varepsilon_t$$

Model 5 (for N=1-3):

$$DyearN_t = C(1) + C(2) * dcpiyy_t + C(3) * ddm2_4_7_t + C(4) * dm2_t + C(5) * dusd_t + C(6) * ECTN_cpi_{t-1} + \varepsilon_t$$

Here ECTN_cpi (_0_2) denotes the error-correction parameter of long-term non-balance with current inflation (expected for 2 months ahead). Table 4 presents results for preferred specifications after removing insignificant variables.

Table 4. Optimal specifications of models with basic fundamental factors

	$\Delta M2_RATE$	$\Delta DM2_4_7$	Δusd	$\Delta usd0_1$	ECTN_cpi_0_2	R ² adj.	St.error
$\Delta year1$	-0.033816***	0.096315**	0.102266*			0.301218	0.591680
$\Delta year3$		0.074108*	0.082571*			0.246845	0.468177
$\Delta year5$			0.060911*		-0.064519*	0.263422	0.368367
$\Delta year10$				0.059911*	-0.041970***	0.262856	0.341353
$\Delta year15$				0.058507*	-0.051810**	0.226914	0.349678

Notes: *significant at 1%, at **5%, at ***10%;

The findings show that the inflationary implications of money supply growth 6 months ago are positively reflected in current changes of the short-term interest rates only. This confirms our resume regarding the analysis of responses of yields to shocks in M2 – four months later the decline of yields is suspended. Moreover, as we expected, long-term rates do not fix the liquidity effect and only slightly move with cash injections. Expectations of currency depreciation / appreciation (and the current change of exchange rates) almost always play a major role in explaining nominal interest rates, yielding the highest positive coefficient. In addition, the factor of future exchange rate expectations for the next month has a higher significance for determining the behavior of long-term government bond yields. No evidence for the fact that current changes in the price level affect bond yields along the yield curve suggests that they are not taken into account when expectations are being formed.

Therefore we have found that the basic theoretical factors have a certain impact on generating zero-coupon nominal yields over the period of 2003-2009, but this impact is of low significance, helping to explain less than a third of yield' variation.

7.3.2. Modelling of complex influence of all the potential determinants on bond yields

At the final step of the research we construct multiple-factor regression models of government bond yields' dependency from macroeconomic, monetary, international factors and economic events.

In all initial model specifications the following factors are included: (event) *DBLIP_03*, *DBLIP_04*, *DBLIP_05*, *DBLIP_05_exp*, *DBLIP_06*, *DUMN*, (international) *ΔBRENTFUT_2M*, *ΔRESERVES*, (macro) *ΔDEBT_REAL*, *ΔGDP_REAL*, (monetary) *ΔDM2_4_7*, *ΔM2_RATE*, *ΔMIACR_1M*, *ΔREPO_MIN*. Adding the factors of inflation and expectations of currency appreciation/depreciation specifies the estimated models:

Model 6 (for N= 1): $\Delta year N_t(\Delta cpi_{yy_12_0_t}, \Delta usd_t)$

Model 7 (for N= 3, 5): $\Delta year N_t(\Delta cpi_{yy_0_2_t}, ECTN_cpi_0_2_{t-1}, \Delta usd_t)$

Model 8 (for N=10, 15): $\Delta year N_t(\Delta cpi_{yy_0_2_t}, ECTN_cpi_0_2_{t-1}, \Delta usd_{0_1_t})$

Table 5 shows results for the preferred models of interest rates which appeared to have the better fit and most effectively reflect the susceptibility of yields to changes in factors among other specifications examined.

Table 5. Estimation results of optimal specifications of multiple-factor models

	$\Delta year1^a$	$\Delta year3$	$\Delta year5$	$\Delta year10$	$\Delta year15^b$
DBLIP_03		0.780097**	0.780983*		
DBLIP_04	-0.683534*	-0.847116*	-0.841185*	-0.466213***	
DBLIP_05			-0.558025**	-1.024162*	-1.179822*
DBLIP_05_EXP			-0.443930***	-0.801486*	-0.959638*
AMIACR_1M	0.111341*	0.100596*	0.059605*	0.053068*	0.049513**
AREPOMIN	0.508722**	0.728418*	0.638684*	0.473185*	0.411260*
DUMN		0.550174*	0.511102*	0.402480*	0.410692*
ECTN_cpi_0_2		-0.082454*	-0.066933*	-0.060932*	-0.060913*
ΔUSD	0.056313**	0.043087*	0.021575***		
ΔUSD0_1				0.026775**	0.029527*
ΔM2_RATE	-0.039260**				
ΔDM2_4_7	0.068693***				
R-squared	0.434093	0.691227	0.691438	0.629510	0.634588
Adjusted R-squared	0.388820	0.662019	0.652868	0.588909	0.600022
S.E. of regression	0.553351	0.313627	0.252883	0.254916	0.251520
F-statistic	9.588433	23.66546	19.92671	15.50457	18.35876
Prob(F-statistic)	0.000000	0.000000	0.000000	0.000000	0.000000

Notes: ^{a, b}Newey-West (HAC) standart errors are used; *significant at 1%, ** significant at 5%, *** significant at 10%,

The main conclusion of the final factor models is the lack of significant effect of international factors (oil prices, international reserves) as well as the fact that bond yields of all maturities are mainly driven by monetary changes. It is observed from the maximum and most significant positive coefficients of the change in repo rate and interbank interest rate as well. The medium-term segment of the yield curve is notable for its maximum sensitivity to changes in the minimum repo rates.

As expected, fiscal and global macroeconomic factors (economic activity) are not at any rate reflected in the dynamics of interest rates, although the result regarding significant influence of current and expected exchange rate is confirmed. It is worth mentioning that the effect of the depreciation risk decreases along the yield curve, at the same time being substantially diminished in comparison to models where only factors of inflation and money supply growth are taken into account. Reaffirming the results of basic models' estimation, there is no direct impact of inflationary expectations on yields of all maturities, which is for 3-15-year maturities offset by a decreasing effect of long-term balancing with inflationary expectations for two months ahead (ECTN_cpi_0_2).

Dummy variables, responsible for market sentiments during the crisis period (dumN), improve the model and demonstrate a reliable difference in the behavior of government bond yields from July 2008 till the end of 2009, which is difficult to be explained by traditional determinants. In other words, the yields on average were 0,5% higher against the impact of identified economic determinants. The significance of blip dummies, reflecting repayment of the foreign government debt to the members of the Paris Club in 2005 (DBLIP_05 and DBLIP_05_exp), verifies our hypothesis that this event had effect on long-term interest rates resulting in their convergence to an average level. This implies the expected decrease of long-term credit risks. On the contrary, information on full repayment of foreign debt in 2006 was not reflected by the market. The increase in political risks in 2003 and their decrease in 2004 are fixed by middle-term yields, though positive sentiments from expected clear policy and less uncertainty in the market in 2004 spread to long-run, being reflected in reduction of 10-year yields as well as enhancing positive dynamics of short-term nominal yields.

Specific behavior of the 1-year bond yield is necessary to be marked out. The findings make it possible to conclude that besides the main effect of money market rates' changes and foreign exchange risk, the short-term rate additionally reflect inflationary implications of money supply expansion and short-term increase in liquidity itself. Concerning the response to political and economic events, only the impact of general decrease of political risks in 2004 is revealed. In whole, the findings of multivariate model estimation repeat those of a model with basic theoretical factors, constituting a low explanatory power of current economic indicators for short-term yields.

Most liquid government bonds of three and five years to maturity more clearly respond to changes in politics, considered inflationary expectations, foreign exchange risk, their yields are more likely to be influenced by changes in economic factors as well as to reflect short-term risks of the financial market (due to the highest coefficients of DUMN).

It is obvious that the examined factors explain a general trend in the Russian government bond yields' dynamics (see Fig. B2). Since mid-2008 market conditions begin to play a major role in affecting investor perceptions and, as a consequence, in generating required rates of return on the market, so estimated relationships may not fully reflect the essence of the problem. A «crisis» dummy variable, included in the analysis, reflects the sentiments prevailing in the market during a period of uncertainty and risk aversion and therefore makes regression models more effective and tracking the major part of crisis changes. But nevertheless, what is seen from the graphs of residuals (Fig.B2), it remains impossible to catch all of the increased volatility.

High absolute values of residuals in the model in some periods (before 2004, since mid-2008) can be explained by the influence of unaccounted factors (volatility, external shocks, political instability, uncertainty about further actions of government regulators, the probability of default, etc.) and by possible market imperfections in estimating premiums and the correct rate of return on sovereign debt. Furthermore, current and expected inflation for 2 months ahead (based on actual future values) may turn out to be incorrect approximations of expectations of changes in CPI, which are built in the required return by market participants. Similarly, currency risk premium may not be fully approximated by exchange rates and their further expectations, based on actual official exchange rates. However, the explanation from 38% (for short-term yield) to 66% of the total volatility of government bond yield in the GKO-OFZ market seems to be an efficient result.

In conclusion, a robustness analysis of results over the period of study is carried out, as a period of crisis changes (from mid-2008) is taken in consideration. Results of Chow test, Ramsey Reset test and traditional tests for stability of estimated coefficients (CUSUM, CUSUMSQ) show evidence in favor of the stability models almost in every case. Accordingly, even in crisis situations identified economic factors continue to have significant impact on yields of government bonds. This conclusion is consistent with the fact that since 2008 the minimum repo rates were constantly rising as well as interbank interest rates against the growing deficit of liquidity. Accordingly, at constantly arranged repo transactions the required yields of used government bonds were increasing.

7. Concluding remarks and discussion

The formation of government securities' rate of return is an important and necessary aspect of financial markets research. This paper investigates the reaction of Russian government bond yields to changes in the list of macroeconomic indicators, indicators of monetary policy and money-market, external factors and features of the current economic and political situation. The study is based on the analysis of zero-coupon yield dynamics of the GKO-OFZ market during

the period from 2003 to 2009 and its historical relationship with the factors under consideration. Various methods of research are applied in order to achieve reliable results, among them cointegration techniques, error-correction models, VAR-models and multifactor regressions take place.

The contribution of the study is fourfold: it gives an overview on the development of Russian government bonds market for the purpose of better understanding of its specific features, singles out and analyzes the potential determinants of the bond yields, assesses the sensitivity of the nominal interest rate to changes in factors under study and identifies the determinants with the most significant contribution to the yield curve dynamics.

Summarizing the overall results of our research, we can conclude that there is no significant influence of external factors on the yield curve in Russia, but the interest rates appear to be mainly driven by the situation in the money market. Indeed, at a fairly rapid development of the repo market, where OFZ are one of the main tools, the average cost of funding in the money market has turned to largely determine the required return on low risk government bonds. Basic factors, such as inflationary expectations, changes in foreign exchange risk and money supply expansion certainly play an important role in determining the dynamics of nominal interest rates, but explain less than a third of a total variation in GKO-OFZ market yield. Rather surprisingly, no evidence in favor of the influence of current inflation and expectations in the short-run is found. Important political and economic events make a contribution to a more precise determination of interest rates movements. In whole, it turns out that the "external" financial indicators dominate the basic segment of the financial market - a segment of the sovereign debt market - more than it affects them. Though, it is not an unexpected finding in case of a specific development of the Russian government bonds market over the observable period.

Additionally, from the results of the analysis of bond yields of various maturities, a weaker susceptibility of long-term rates to the current changes and a more substantial role of inertia of their dynamics should be noted. Short-term bonds respond less to the significant factors due to a higher role of subjective moods in the market and a dynamic volatility inherent in the behavior of this segment of the yield curve. What is more, a brief robustness analysis gives evidence that the exposure of the identified determinants is moderately robust. This implies the presence of significant effect of changes in identified informative economic factors on bond yields even during the crisis tendencies.

It is obvious that the results of the study, to some extent, suggest a discrepancy between changes in the GKO-OFZ market yields and an idea of yield formation according to market rules. Among the most important reasons for that are qualitative features of the GKO-OFZ market, such as low market capacity, very low and heterogeneous liquidity, lack of interest of

market participants to invest in negative real interest rates, "narrow" main base of investors and a frequent "forced" necessity to invest in riskless bonds (low yield does not prevent state banks from investing, but also prevents to attract capital of private sector and reduces the interest in OFZ for funding) as well as tough monitoring the situation on the government bonds market and supporting the low rate of return by government regulators. It is worth mentioning that after 2009 trends and driving forces in the government securities market may change because of the possible gradual increase in the proportion of non-residents, the transition to the concept of deficit budget and dynamic growth of domestic loans.

Thus, the research presented has contributed much to a deeper understanding of the mechanisms that generate changes in the nominal rate of return on government bonds in specific Russian circumstances.

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Appendix A

Table A1. Behavior of the Russian domestic government debt

	2002	2003	2004	2005	2006	2007	2008	2009
GDP (billion rubles)	10830,5	13243,2	17048,1	21625,4	26903,5	33258,1	41444,7	39063,6
Domestic debt (billion rubles)	654,514	663,534	759,791	851,121	1028,036	1248,848	1421,439	1837,164
Domestic marketable debt (bonds, billion rubles)	643,014	652,034	759,791	851,121	975,621	1147,433	1244,024	1569,749
Domestic debt/GDP, %	6,04%	5,01%	4,46%	3,94%	3,82%	3,76%	3,43%	4,70%
Domestic marketable debt/GDP, %	5,94%	4,92%	4,46%	3,94%	3,63%	3,45%	3,00%	4,02%

Table A2. Zero-coupon bond yields' descriptive statistics

Feb.2003-Dec.2009					
	1-year	3-year.	5-year	10-year	15-year
Mean	6.173133	7.444578	7.723614	8.121205	8.246145
Maximum	11.57000	13.11000	11.67000	11.74000	11.77000
Minimum	2.570000	5.520000	6.060000	6.520000	6.660000
St. deviation	1.734921	1.863093	1.563407	1.528318	1.529116
Jul.2008-Dec.2009					
Mean	8.632778	10.11000	9.814444	10.22167	10.36444
Maximum	11.57000	13.11000	11.67000	11.74000	11.77000
Minimum	4.930000	6.060000	6.360000	6.940000	7.130000
St. deviation	1.902128	2.132720	1.619587	1.489114	1.451240

Appendix B

Table B1. Correlation coefficients between yields (first differences) and some of considered factors

	1-YEAR	3-YEAR	5-YEAR	10-YEAR	15-YEAR		ΔYEAR1	ΔYEAR3	ΔYEAR5	ΔYEAR10	ΔYEAR15
ΔDEBT_REAL	0.0595	0.0619	0.0777	0.0976	0.1038	ΔCORR_RATE	-0.2172	-0.0758	-0.0649	-0.0667	-0.0649
ΔGDP_REAL	-0.1522	-0.0760	-0.0355	-0.0195	-0.0149	ΔM2_RATE	0.3609**	0.2957**	-0.2405	-0.1846	-0.1591
ΔBRENTREL	-0.0589	-0.0148	-0.0003	0.0261 ²²	0.0357	ΔUSD3-0	0.3473	0.4259	0.4038	0.3823	0.3632
ΔBRENTFUT_1M	-0.1296	-0.0734	-0.0443***	-0.0115***	-0.0002***	ΔUSD2-0	0.4651	0.5384	0.4573	0.4264	0.4049
ΔBRENTFUT_2M	-0.1493	-0.0907	-0.0576**	-0.0224**	-0.0098**	ΔUSD	0.5075*	0.5617*	0.4633*	0.4233*	0.4016*
ΔRESERVES	-0.3629*	-0.3461*	-0.2975*	-0.3158*	-0.3234*	ΔUSD0-1	0.0415	0.4567	0.4563**	0.4989**	0.5041
REPO_MIN	0.8648*	0.8821*	0.7897*	0.7697*	0.7590*	ΔUSD0-2	0.2758	0.5009	0.3929	0.3854	0.3746
MIACR_1M	0.7866*	0.7300*	0.6074*	0.5896*	0.5825*	ΔUSD0-3	0.2858	0.4057	0.2851	0.2638	0.2507
CPIYY_12_0	0.4405*	0.6474*	0.7198*	0.6850*	0.6689*	In bold lines estimation of expectations is provided: among Brent prices the most relevant is the factor of 2-month futures price; among CPI - current inflation and 1-2-month expectations are further analyzed; among exchange rate variations the most relevant are the factors of current rate of change and 1-3-month expectations.					
CPIYY	0.2726**	0.3670**	0.3777**	0.3749**	0.3719**						
CPIYY_0_1	0.2473**	0.3313**	0.3363**	0.3354**	0.3332**						
CPIYY_0_2	0.2148**	0.2881**	0.2887**	0.2884**	0.2879**						

Notes: *significant at 1%, ** at 5%, *** at 10%

Table B2. Unit-root test results

	ADF-test ²³ (p-value)	PP-test (p-value)	KPSS-test (statistic)	ADF-test (first differences) (p-value)		ADF-test (p-value)	PP-test (p-value)	KPSS-test (statistic)
1_YEAR	0.2241*	0.1618*	0.173575*	0.0000	ΔUSD	0.0000	0.0000	0.159852
3_YEAR	0.1575*	0.3683*	0.218826*	0.0000	ΔUSD0-1	0.0000	0.0000	0.176333
5_YEAR	0.3207*	0.4571*	0.243566*	0.0000	ΔUSD0-2	0.0002	0.0002	0.164275
10_YEAR	0.5625*	0.5645*	0.248628*	0.0000	ΔUSD0-3	0.0043	0.0031	0.149604
15_YEAR	0.6262*	0.6097*	0.250459*	0.0000	ΔM2_RATE	0.1074*	0.0000	0.082018
REPO_MIN	0.1552*	0.3055*	0.169390*	0.0002	MIACR_1m	0.0493	0.0910*	0.144008
ΔM2_4_7	0.1961*	0.0147	0.166525*	0.0079	ΔBRENTFUT_2M	0.0000	0.0000	0.066539
CPIYY	0.2253*	0.3266*	0.144797	0.0000	ΔRESERVES	0.0003	0.0003	0.108745
CPIYY_0_1	0.0550*	0.3485*	0.138080	0.0028	ΔDEBT_REAL	0.0005	0.0000	0.255622
CPIYY_0_2	0.0931*	0.3376*	0.131850	0.0234	ΔGDP_REAL	0.0000	0.0000	0.072125
UST10Y	0.1519*	0.1337*	0.255166*	0.0000	Notes: *time series is nonstationary at 5% value of significance according to the test hypothesis			
CPIYY_12_0	0.0193	0.2712*	0.190408*	0.0096				

Table B3²⁴. Testing of the impact of inflation on changes in bond yields with a possible balancing of deviations from long-term balance

	Δyear1		Δyear3		Δyear5		Δyear10		Δyear15	
	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value
ECTN	-0.064986	0.0927	-0.081408	0.0001	-	-	-	-	-	-
ΔCPIYY	0.065641	0.6281	-0.045364	0.4636	0.088700	0.3334	0.096711	0.3059	0.112553	0.1875
ECTN	-	-	-0.166253	0.0006	-0.050695	0.2625	-0.068457	0.0607	-0.048864	0.0680
ΔCPIYY_0_1	0.179292	0.2154	0.018048	0.8358	0.143254	0.2542	0.121861	0.2898	0.119343	0.2220
ECTN	-	-	-0.075110	0.0000	-0.094816	0.0307	-0.071575	0.0504	-0.050360	0.0594
ΔCPIYY_0_2	0.106255	0.3074	-0.029422	0.6764	0.056509	0.7153	0.078375	0.5641	0.100290	0.3583

²² We assume positive correlation coefficients between long-term yields and Brent price as not representative;

²³ Constant and trend is used in the test regressions of ADF and PP tests only if coefficients are significant at 10%; KPSS's asymptotic critical values (5%) are 0.146 for bond yields, dm2_rate, miacr_1m, repo_min, dm2-4_7, dreserves, ust10y and cpiyy_12_0, and 0.463 otherwise.

²⁴ The constant term has been omitted for notational convenience; the lack of cointegration between 5-year bond yield and expectations for one month ahead are assumed as unrepresentative;

$\Delta CPIYY_{12,0}$	0.595010	0.0091	0.266551	0.0409	0.462574	0.0083	0.442545	0.0073	0.414168	0.0126
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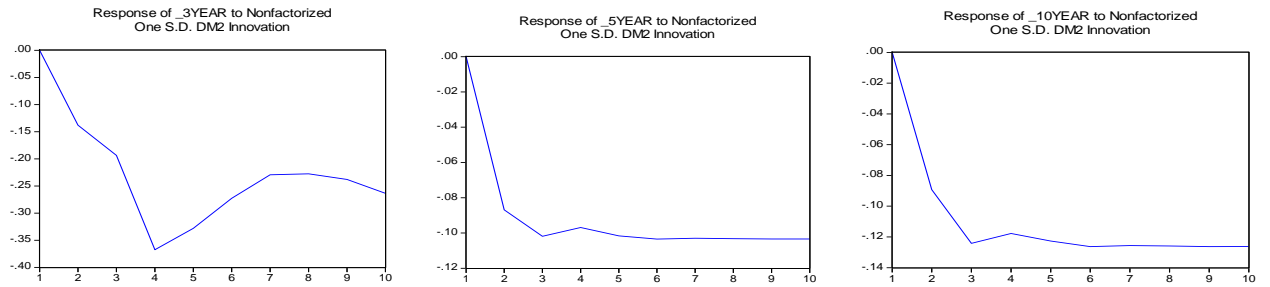


Fig.B 1 Response functions of bond yields of 3-5-10 years to maturity to shocks in rate of M2 growth

Table B4. Testing of the impact of foreign debt market yield on changes in Russian bond yields with a possible balancing of deviations from long-term balance (P-values in parenthesis)

	$\Delta year1^{**}$	$\Delta year3^{**}$	$\Delta year5$	$\Delta year10^*$	$\Delta year15^*$
ECTN	-0.041842 (0.2886)	-0.060307 (0.2004)	-0.090087 (0.0217)	-0.096417 (0.0346)	-0.100512 (0.0323)
$\Delta ust10y$	-0.137500 (0.5543)	-0.128494 (0.3431)	-0.137764 (0.3144)	-0.200516 (0.3719)	-0.218481 (0.3113)
Δusd_t	0.113810 (0.0000)	0.080735 (0.0000)	0.059154 (0.0001)	0.049787 (0.0001)	0.047039 (0.0002)
abs(Δust_{10t})	1.023015 (0.3414)	1.002840 (0.3296)			
R ² adj.	0.273199	0.311880	0.241779	0.228209	0.218398

Notes: * Newey-West (HAC) errors are used; ** autocorrelation is corrected by the procedure of Cochrane-Orcutt

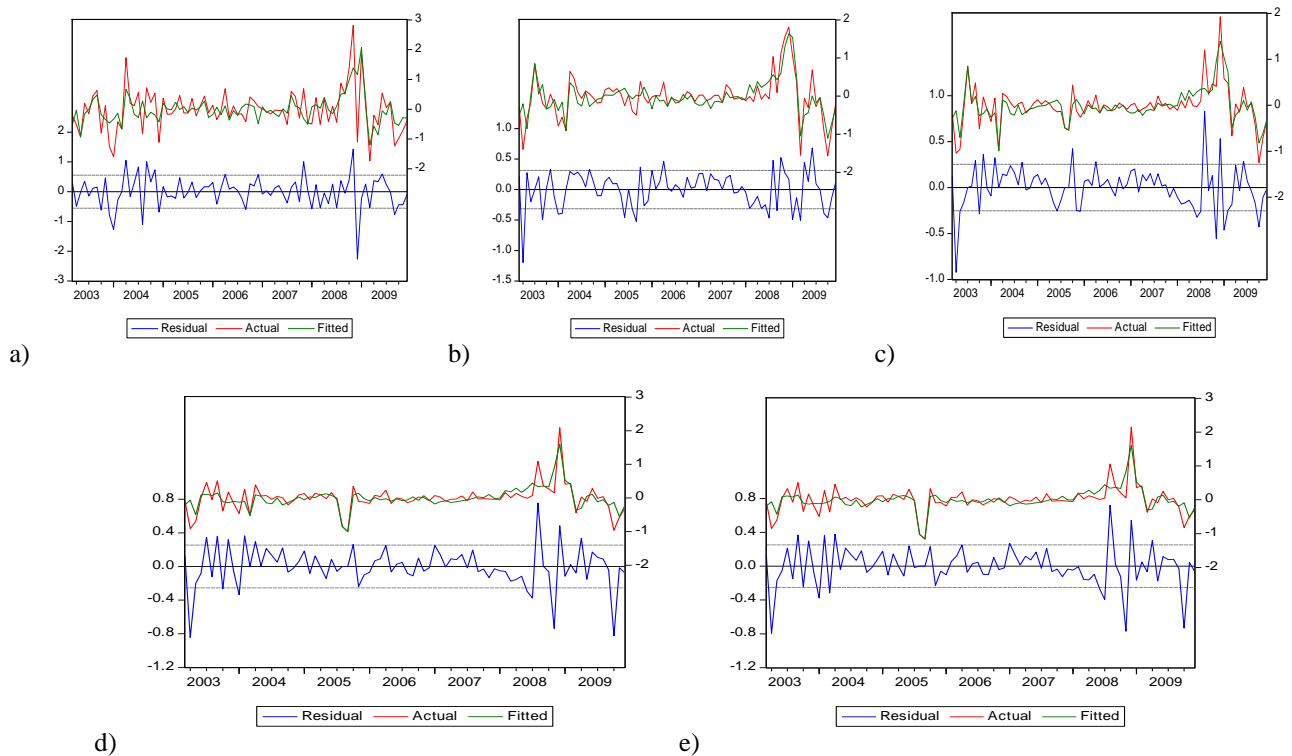


Fig.B 2. Residuals, actual and fitted first differences of yields from multiple-factor models
(a) 1-year, b) 3- year, c) 5- year, d) 10- year, e) 15- year