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Robotizing bond portfolio selection on the Russian debt market on the basis of a modified strategy of riding the yield curve*

Eugene A. Korobov[a]
E-mail: korobovea@yandex.ru

Yulia V. Semernina[b]
E-mail: ysemernina@yandex.ru

Alina S. Usmanova[b]
E-mail: alina.brosalova@yandex.ru

Kristina A. Odinokova[b]
E-mail: odinokova.kristina93@mail.ru

[a] Saratov State University
Address: 83, Astrakhanskaya Street, Saratov 410012, Russia

[b] Yuri Gagarin State Technical University of Saratov
Address: 77, Polytechnicheskaya Street, Saratov 410054, Russia

Abstract

The modern global debt market features historically low average interest rates, convergence of yields on bonds with different maturities, an increase of yield curve inversion emergence frequency and a large-scale trend to automate financial decision making. The researchers' attention in these fields is mainly focused on designing models that describe the state of the debt market as whole or its individual instruments in particular, as well as on risk management methods. At the same time, the specialized literature offers very few works concerning the topic of computer algorithms for bond portfolio selection based on traditional or advanced investment strategies. The aim of the present research is to create a modification of the existing algorithm of riding the yield curve strategy application, employing, first, average bond yield over the holding period instead of traditional bond yield to maturity; second, a developed algorithm for calculating the market spread on bonds; and, third, alternative risk evaluation indicators (compensation coefficients), which allow us to measure

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objectively price risk, liquidity risk, transaction costs risk and a general risk. The modification and the development of the algorithm for calculating the market spread were carried out using the direct measurement of the result technique, which entails application of the strategy to the data on bond issues received through the Moscow Exchange API. The selection of financial instruments was conducted in all sectors of the Russian debt market: public bonds, sub-federal and municipal bonds, corporate bonds. The modified algorithm enabled us to get extra yield for each selected bond issue, thereby proving the high effectiveness of the technique compared to the traditional strategy. Software implementation of the algorithm can be integrated into any robotized or semi-robotized stock exchange trading application.

Key words: modified riding the yield curve strategy; robotizing bond portfolio selection; algorithm for calculating the market spread on bonds; compensation coefficients; bond price risk; bond liquidity risk; bond transaction costs risk; general bond risk; investment software applications.

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Introduction

The development of financial technologies and financial markets in recent decades has led to the fact that today almost all decisions on purchase or sale of financial instruments are carried out through specialized electronic applications. Their software architecture is largely determined by the financial tasks that a market actor sets for himself. Speculative strategies such as scalping, intraday or swing trading are implemented today mainly by creating trading robots for high-frequency trading. Human participation in making a decision to buy or sell a particular financial instrument, in this case, although it may be present, is usually minimized.

Following the investment strategies today involves engaging three types of software:

- fully robotized applications that exclude human participation (the first type);
- semi-robotized complexes, when the program forms investment options, and a person decides on the acceptance of one or another option (the second type);
- non-robotized systems in which all financial analysis and decision making is a matter of investor's responsibility (the third type).

All three types of investment applications have been actively developing in recent years. The first type of software can be classified as robo-advisors that have been gaining popularity after the financial crisis of 2008. They use artificial neural networks and graph models of decision making. Algorithms of their work [1–4], based on the classical principles of portfolio selection by H. Markowitz, W. Sharpe and J. Tobin, showed high effectiveness in a growing market during the period from February 2009 to February 2020. A "Black Swan" in the form of a collapse of stock indices in March 2020 led to the case when many FinTech providers had to switch the work of their robo-advisors to manual control mode. This once again indicated the limitations of artificial intelligence system applicability for making financial decisions.

Semi-robotized investment applications can include trading systems in which an investor makes transactions based on data received from an integrated screener working with such instruments as stocks, mutual funds, ETFs, bonds, etc. The "intelligence" of such screeners usually comes down to calculating the main economic indicators of a financial instrument or an issuing organization and filtering them according to a given criterion.

Non-robotized applications comprise most of the trading terminals provided by stock brokers and banks to their clients for making transactions in the financial market.

All of the above trends are to be taken into account, first of all, by such institutional investors as mutual funds, as well as more conservative market actors — commercial banks, public and private pension funds, insurance companies and some private investors who face the task of creating low-risk portfolios. The majority of investments in such portfolios are usually government and corporate bonds. One of the possible universal strategies for selecting financial instruments in the debt market is the riding the yield curve strategy (RYCS).

Modern Russian academic literature lacks works analyzing active investment strategies in the bond market; moreover, the modifications of such strategies are practically absent as well. The most common approach to bond investing is the "buy and hold" strategy, which can be traced in the papers by N.F. Korobov and A.A. Beloglazov [5], A.A. Ponomarev [6], N.V. Popova [7], P.A. Lashevsky [8], I.A. Darushin [9], A.N. Zadorozhnaya [10], V.V. Nazarova and I.P. Levichev [11], I.A. Freidina [12], M.V. Fomina, Yu.V. Lakhno and A.P. Pyshnograya [13] and other authors.

Some researchers study the shape of the bond yield curve, but they do not consider its application to RYCS (for example, a similar approach is a characteristic of the papers by A.Y. Mikhailov [14], A.N. Burenin [15], S.V. Beshenov and V.A. Lapshin [16]).

RYCS is practically not considered in the specialized Russian financial and economic literature, and in foreign literature its most complete description is presented in the fundamental works by F.J. Fabozzi [17–19]. A detailed consideration of this strategy with an analysis of its practical use also can be found in the papers by V. Galvani and S. Landon [20], D. Bieri and L. Chincarini [21], R. Cox and J. Felton [22], Z. Wei, W. Xianhua and W. Guofu [23].

An effectiveness estimation of RYCS under the conditions of low interest rates is presented in a study by the International Monetary Fund [24].

Computer models of bond portfolio selection and evaluation are also presented rather sparsely in the works of Russian and foreign researchers. Russian papers on this topic can be found in [25, 26].

The choice of RYCS as an object of robotization is due to a combination of two factors. On the one hand, under the conditions of low interest rates and the inverted yield curve shape, this strategy (with sufficient credit quality of bond issuers) has a certain "resistance" to the risks associated with the debt market, primarily to the interest rate growth risk; the probability of its realization today is objectively quite high (especially when applying the strategy on a short section of the yield curve). On the other hand, RYCS belongs to the group of well-formalized investing strategies, which allows us to form unambiguous algorithms for robo-trading. In addition, RYCS is available not only to institutional, but also to private investors, whose distinctive feature is the insignificant volume of the portfolio, a priori assuming a limited level of its diversification.

The initial condition determining the possibility of using this strategy is the presence of a positive difference between the yield of bonds with a longer maturity and the yield of bonds with a shorter maturity (in fact, we are talking about the presence of a "classic" upward slope of the bond yield curve). As an additional condition for its application, it is necessary to note a sufficient level of market liquidity of the bond issue and an appropriate level of transaction costs.

Currently, in the context of a global decline in the average level of interest rates, bond yields with different maturities are "converging" (minimizing the difference in bond yields on different sections of the curve), and the frequency of the bond yield curve inversion is significantly increasing. These trends lead to the need to transform the approach to considering strategy: its use in the classical interpretation makes investors accept increased interest rate risk, liquidity risk and transaction cost risk, while the resulting yield generally does not compensate for the accepted risks.

The purpose of this study is to design a modification of the traditional RYCS, taking into account the interest rate curve shape, as well as the development of an automated algorithm for calculating the market spread in the Russian debt market which allows investors to evaluate the liquidity risk. The algorithms thus obtained can be engaged by exchange trading software of the first and second types.

1. Methods

The modification of RYCS and the development of an automated algorithm for calculating the market spread is supposed to be carried out using the method of the result direct measurement. This method involves the application of a modified RYCS to real data (based on information received from the Russian exchange bond market at a specific time – a "market snapshot" for a specific date) and does not involve the design of predictive, descriptive or simulation models for the Russian bond market as a whole or of its individual sectors in particular.

This method is based on the following assumptions:

1) the costs of investors in the purchase and sale of bonds include two types of commissions – the exchange commission and the broker's commission, charged as a percentage of the amount of actually completed transactions, while other types of costs are not considered;
2) bonds are selected for the investment portfolio during one trading session;
3) the closing prices of the corresponding trading session are considered as settlement prices for the purchase and / or sale of bonds, regardless of the volume of transactions performed, while in the absence of real transactions during the trading session, the bond issue is deemed not to have a sufficient level of liquidity and is not selected to the bond portfolio;
4) when calculating the yield indicators for bond issues, the accumulated coupon income at the time of the relevant transaction is taken into account;
5) the credit quality of bond issuers is assumed to be unchanged throughout the analyzed period (this study doesn't separately assess or analyze it).

Considering modification of RYCS is based on following points:

1) the average yield of bonds over the investment period instead of the traditional yield of bonds to maturity;
2) the designed author's algorithm for calculating the market spread on bonds;
3) alternative risk assessment indicators (compensation coefficients) that make possible an objective assessment of price risk, liquidity risk and transaction cost risk, as well as overall risk.

The quantitative indicators proposed within the modified strategy are universal for the debt market and can be applied to any coupon and discount bonds. The generalizing nature of the indicators used is due to the chosen technique of their design: when calculating them, fixed parameters of bond issues are used, as a rule, determined at the moment of issue of the latter, data on market transactions with bonds and their market quotations, as well as information on the time bonds are held (investment period).

When using RYCS within the traditional approach, it is assumed that the classical formula is applied to calculate the yield of bonds to maturity:

$$Y_M = \frac{(P_S - P_P)}{P_P} \cdot \frac{365}{t_M} \cdot 100\%, \quad (1)$$

where Y_M – bond yield to maturity;

P_S – sale price or redemption price of bonds;

P_P – bond purchase price;

t_M – the number of days remaining until the bonds are redeemed.

It should be emphasized that for the classical version of the strategy, strict inequality is mandatory:

$$Y_{LT} > Y_{ST}, \quad (2)$$

where Y_{LT} – is the yield to maturity of bonds with a long maturity;

Y_{ST} – yield to maturity of bonds with a shorter maturity.

In addition, another strict inequality must also be observed:

$$Y_M > Y_E, \quad (3)$$

where Y_E – expected return on investment.

Within the consideration modification, it is proposed to focus on an alternative indicator – the yield for the period of holding the bond, which is due to the availability of an objective opportunity for investors to sell bonds without waiting for their redemption. The calculation of this indicator can be done according to the following formula:

$$Y_{t_H} = \frac{(P_S + C_S + \sum_{i=1}^{n} C_{R_i} - P_P - C_P - \sum_{j=1}^{k} T_j)}{P_P + C_P} \times \frac{365}{t_H} \times 100\%, \quad (4)$$

where Y_{t_H} – yield for the period of holding the bond;

C_S – is accumulated coupon yield at the time of bond sale;

C_{R_i} – is the coupon yield paid by the issuer for the corresponding coupon period (subject to availability of such payments for the holding period);

n – is total number of coupon periods for bonds;

C_P – is accumulated coupon yield at the time of bond purchase;

T_j – transaction costs;

k – total number of transaction cost types;

t_H – number of days the bond is held.

Unlike the traditional technique, the yield indicator for the period of holding the bond should be calculated regularly, for example, at the end of each trading session, and not only at the time of bond purchase. This approach initially implies a higher level of investor trading activity compared to the traditional one.

To assess the effectiveness of the modified RYCS, it is advisable to use the average yield indicator for the investment period, taking into account both the periods of bond holding and the periods of no positions in bonds:

$$\overline{Y} = \frac{\sum_{l=1}^{m} Y_{t_{H_l}} t_{H_l} + \sum_{q=1}^{v} Y_{t_{0_q}} t_{0_q}}{\sum_{l=1}^{m} t_{H_l} + \sum_{q=1}^{v} t_{0_q}}, \qquad (5)$$

where $\overline{Y}$ – average yield over the investment period;

$Y_{t_{H_l}}$ – yield for the l-period of bond holding (the period of availability of positions on bonds);

m – number of bond holding periods;

$Y_{t_{H_l}}$ – yield for the period of no positions in bonds (for example, due to the placement of funds on the money market);

t_{0_q} – duration of the period with no positions in bonds;

v – number of periods with no positions in bonds.

Conceptually, it is important to note that for a modified RYCS, the ratio between bond yields of different durations takes the form:

$$Y_{LT} \geq Y_{ST}. \qquad (6)$$

Thus, the proposed modified strategy is effective even when the bond yield curve is flat.

In turn, to evaluate the price risk, it is suggested to use the change in the bond market price with an increase in interest rates by 1%:

$$\Delta_{+} = \left| P_{S_{Y+1\%}} - P_{P} \right|, \qquad (7)$$

where Δ_{+} is the change in the bond market price with an increase in interest rates by 1%;

$P_{S_{Y+1\%}}$ – the bond market price with an increase in interest rates by 1%.

The value $P_{S_{Y+1\%}}$ is calculated according to formula (4) by selecting such a numerical value of this indicator, at which the value of the bond yield will increase by exactly 1% ($Y_{M+1\%}$). This makes it possible to obtain accurate results (in absolute terms), which is the main advantage of this indicator compared, for example, with classical or modified duration, which is less accurate. In general, it assumes an approximate calculation of the coupon rate; it does not take into account the daily accrual of accumulated coupon income; does not consider the payment of the latter at the end of the coupon period or pay back by the buyer at the time of bond sale. Duration also assumes complete symmetry of changes in bond prices both in terms of growth and in terms of declining interest rates (the last problem can be solved to a certain extent by using the convexity index of bonds; however, when liquidity is limited, this indicator has limited representativeness).

As a risk indicator that reckons the accrual of current bond yield, we proposed to use the author's price risk compensation coefficient, determined by the formula:

$$K_{CP} = \frac{\Delta_{+}}{C_D}, \qquad (8)$$

where K_{CP} is price risk compensation coefficient;

C_D – the value of the coupon charged daily.

Thus, the value of the price risk compensation coefficient can be interpreted as the number of days for which the value of the coupon charged on bonds fully compensates for the estimated drop in the bond price (from their current market prices) with an increase in the interest rate average level by 1%.

Another indicator that makes it possible to assess the risk taken by investors in the debt market is the liquidity risk compensation coefficient calculated by the formula:

$$K_{CL} = \frac{\overline{S}}{C_D}, \qquad (9)$$

where K_{CL} is liquidity risk compensation coefficient;

$\overline{S}$ – average value of the market spread for a bond issue.

We propose to interpret the value of the liquidity risk compensation coefficient as the number of days for which the value of the coupon charged on bonds fully compensates for the average market spread on bonds.

The average value of the market spread (in absolute or relative terms) for a certain period of time objectively reflects the level of liquidity of bonds and is more representative compared to the traditionally used spread at a specific time (usually at the time of opening a position in bonds). The fact is that the average value of the market spread considers every change in bond market quotations (both purchase and sale quotations) during market trading; that is, it reflects the average actually observed difference between them. The absolute advantage of this indicator is the possibility of its systematic calculation, especially if the average spread is calculated over a sufficiently long time interval (for example, a month).

The traditionally used market spread calculated at a specific time has two serious drawbacks: firstly, it cannot always be determined (in particular, in the complete absence of quotations for the purchase or sale of bonds), and secondly, the market spread value at a specific time can deviate significantly from its average values in any direction.

In addition, the classical version of calculating the market spread in absolute terms usually does not reckon the volume of the best bid and ask bond orders, i.e. the spread is "mechanically" calculated as the difference between the best ask price and the best bid price according to the following formula:

$$S_M = B_S - B_P, \qquad (10)$$

where S_M – market spread on a bond issue at a specific time;

B_S – the best ask price on a bond issue at a specific time;

B_P – the best bid price on a bond issue at a specific time.

This technique has gained widespread use because, in practice, the correct calculation of the average market spread "manually" is an extremely difficult and time-consuming task. Its solution involves regular depth of market (order book) monitoring for each bond issue, fixing the changes occurring in it and calculating the market spread for each bond issue at a specific time. When forming a diversified bond portfolio, this task is objectively impossible without the use of automated algorithms.

In this study, an algorithm for calculating the market spread on bond issues was designed and programmed in Lua in integration with the QUIK trading terminal ("Quickly Updatable Information Kit") and assumes the following steps:

1) the selection of bond issues in user mode (at this stage, the investor can choose an arbitrary list of bond issues whose issuers satisfy him in terms of credit quality; other criteria for the formation of this list can be set arbitrarily);
2) setting up the period for fixing market quotations of selected bond issues (by default, the full duration of the main trading session is set, if necessary, it can be changed arbitrarily);
3) setting up conditions for fixing market quotations of selected bonds (default fixing is executed only if there are simultaneous market quotations for the buy and sell; other possible conditions of fixing: if there are market quotations for the buy, if there are market quotations for the sell, permanent fixing);
4) recording the market quotations to the information system (carried out in a specialized register in the database);
5) setting of the period for calculating the market spread (by default it is 20 trading days; if necessary, it can be set arbitrarily);

6) calculation of the average market spread on the bond for the chosen period, carried out according to the formula:

$$\overline{S} = \frac{\sum_{l=1}^{w} S_{M_l} t_l}{\sum_{l=1}^{w} t_l}, \quad (11)$$

where w – the number of price stability periods of bond market quotations (during this period, the value of the market spread remains unchanged);

S_{M_l} – the market spread value during the l-period of price stability of bond market quotations;

t_l – duration of the price stability period of bond market quotations (calculated with an accuracy of 1 second);

7) the output of calculated values of the average market spread to the report (the report form is configurable in user mode).

The use of the single transaction criterion in combination with the developed algorithm allows for a much more accurate assessment of the bond liquidity risk characteristic when using RYCS.

From the automation point of view, the main advantage of the proposed algorithm for fixing and calculation of the market spread on bonds is the regular receipt of objective information about the average actual (actually observed) market spread value on circulating bonds and, if necessary, collecting an array of spread historical data, which allows us much more accurately to characterize the liquidity level of bonds considered as potential investment instruments.

An additional indicator that reflects the level of risk taken by investors is the transaction cost compensation coefficient K_{CT}:

$$K_{CT} = \frac{\sum_{j=1}^{k} T_j}{C_D}. \quad (12)$$

The economic interpretation of this indicator is largely similar to the previous ones: it shows the number of days for which the value of the coupon charged on the bonds fully compensates for the amount of transaction costs incurred by the investor when making transactions on the bond market.

Based on the above indicators, you can calculate the overall compensation factor K_{CG}:

$$K_{CG} = K_{CP} + K_{CL} + K_{CT}. \quad (13)$$

This indicator allows us to get an idea of over what period (number of days) the value of the coupon charged on bonds fully compensates for the price and liquidity risk, as well as the amount of transaction costs. In general, the higher the value of all the above compensation ratios, the higher the level of risk taken by investors, and vice versa.

Obviously, within modified RYCS, maximization of the average yield over the investment period and minimization of the overall compensation coefficient are optimal.

2. Results

The method of the result direct measurement in relation to the modified RYCS was carried out in the Russian exchange bond market as of June 30, 2020 (the date of opening bond positions).

The bond portfolio was formed with borrowed funds attracted at a rate of 7.00% per annum for 90 days, while there is a possibility, if necessary, to prolong the loan (the prolongation is carried out on identical terms in terms of cost and terms of attraction).

Bond issues with maturity dates within 13 to 27 December 2020 are considered as investment objects. Bond issues are selected in all segments of the Russian bond market: government bonds, sub-federal and municipal bonds, corporate bonds (the list of bonds traded in the

Russian stock market and having the required maturity is given in *Table 1*).

The formed list of bond issues contains one issue of government bonds and 15 issues of corporate bonds (in the segment of sub-federal and municipal bonds during this period, bond issues were not redeemed).

The next consistently applied criterion for reducing the list of potential investment objects is the criterion of liquidity, in particular, one that assumes the completion of at least one transaction during the trading session, in which the bond portfolio is formed (data on transactions made on June 30, 2020 in the domestic exchange market are presented in *Table 2*; bold font there marks those bond issues which have no transactions during the trading session).

Table 1.

Bond issues circulating in the Russian stock market with maturity dates within 13 to 27 December 2020, placed no later than 30 June 2020[1]

# / item	Bond market segment	Name of bond issue	Maturity date of the bond issue (dd.mm.yyyy)	Nominal value of the issue, billion rubles
1	Government bonds	GSO–36002–PPS	16.12.2020	15.00000
2	Corporate bonds	Ofir–KO–P02	14.12.2020	0.10000
3		DOM.RF–20–ob	15.12.2020	5.00000
4		Sberbank–001–41R–bso	15.12.2020	3.00000
5		FPK Garant–Invest–001R–03	16.12.2020	1.00000
6		Agronova–L–1–ob	17.12.2020	5.00000
7		RSG–Finans–4–bob	17.12.2020	2.00000
8		SoftLain Treid–001R–01	17.12.2020	3.00000
9		Bank VTB–B–1–48	18.12.2020	10.00000
10		UOMZ PO–2–bob	18.12.2020	1.50000
11		Passazhirsky port–1–obn	22.12.2020	0.00009
12		Bank VTB–B–1–48	23.12.2020	5.00000
13		Magnit–003R–03	24.12.2020	10.00000
14		ChTPZ–001R-01–bob	24.12.2020	5.00000
15		Sberbank–001–179R–bso	25.12.2020	3.00000
16		GPB–25–bob	26.12.2020	5.00000

[1] Bond Screener 'RusBonds'. FinMarket Information Agency (https://www.rusbonds.ru/srch_simple.asp)

Table 2.

The number of transactions concluded on the selected bond issues on June 30, 2020 on the Moscow Exchange (in the 'T + Market Transactions' trading mode)[2]

# / item	Name of bond issue	Transaction volume, RUR	Transaction volume, units	Number of transactions, units
1	**GSO-36002-PPS**	**0**	**0**	**0**
2	**Ofir-KO-P02**	**0**	**0**	**0**
3	**DOM.RF-20-ob**	**0**	**0**	**0**
4	**Sberbank-001-41R-bso**	**0**	**0**	**0**
5	FPK Garant–Invest–001R–03	63526.60	63	10
6	**Agronova-L-1-ob**	**0**	**0**	**0**
7	RSG–Finans–4–bob	1438103.50	1439	50
8	SoftLain Treid–001R–01	683453.75	1336	35
9	Bank VTB–B–1–48	9276796.40	9229	27
10	UOMZ PO–2–bob	143036.00	141	5
11	**Passazhirsky port-1-obn**	**0**	**0**	**0**
12	**Bank VTB-B-1-48**	**0**	**0**	**0**
13	Magnit–003R–03	177337.70	174	13
14	ChTPZ–001R–01–bob	122784.00	120	2
15	Sberbank–001–179R–bso	4090890.60	4221	23
16	GPB–25–bob	1773540.40	1747	10

The liquidity criterion used made it possible to reduce the number of bond issues from 16 to 9, while the latter were used to calculate the yield for the expected holding period (subject to bond holding until maturity), based on the average broker's commission of 0.01% of the transaction amount and the exchange commission of 0.01% of the transaction amount (See the calculation results in *Table 3*).

Thus, 7 out of 9 selected bonds (they are marked in bold in *Table 3*) are not advisable to use within the modified RYCS: their estimated yield for the expected holding period, taking

[2] Moscow Exchange MICEX-RTS (https://www.moex.com/ru/market-data/bulletins/#/date=2020-06-30)

Table 3.

Estimated yield over the expected holding period of the selected bonds (assuming bond holding until maturity)

# / item	Name of bond issue	The yield for the expected holding period, % per annum
1	FPK Garant–Invest–001R–03	9.90
2	RSG–Finans–4–bob	10.94
3	**SoftLain Treid-001R-01**	**6.07**
4	**Bank VTB-B-1-48**	**4.47**
5	**UOMZ PO-2-bob**	**6.11**
6	**Magnit-003R-03**	**3.69**
7	**ChTPZ-001R-01-bob**	**5.12**
8	**Sberbank-001-179R-bso**	**6.65**
9	**GPB-25-bob**	**4.43**

Table 4.

Estimated compensation coefficient values for selected bonds

# / item	Name of bond issue	K_{CP}, days	K_{CL}, days	K_{CT}, days	K_{CG}, days
1	FPK Garant–Invest–001R–03	13.5	27.1	1.2	41.8
2	RSG–Finans–4–bob	14.7	10.6	1.3	26.6

into account the accumulated coupon yield and the transaction costs amount, is less than 7.00% per annum.

For two bond issues with a yield exceeding the cost of raising borrowed funds, compensation ratios (for the case of selling bond issues) were determined as of June 30, 2020.

The calculation of compensation coefficients is performed using classical mathematical and computer modeling methods: determination of the market bond price volatility with an increase in interest rates by 1% (using iterative methods of value selection), as well as calculation and verification of the significance of the bond market spread average value for bond issues based on small samples, followed by verification by the Bartlett criterion (See the calculation results in *Table 4*).

For both bond issues, the overall compensation coefficient is less than the expected investment period, so the selected bond issues can be included in the bond portfolio as part of a modified RYCS. The relative share of each bond issue is determined in inverse proportion to the overall compensation coefficient values, i.e. the share of the bond issue FPK Garant-Invest-001R-03 will be 38.9%, and the share of the issue RSG-Finance-4-bob – 61.1%.

Performance evaluation of the implemented investment strategy was carried out as of September 18, 2020.

The specified date was the date of the bond portfolio review and the adoption of a key investment decision to close the existing bond positions or to continue investment (the calculations are presented in *Table 5*).

The modified strategy made it possible to obtain additional yield on each of the selected bonds, and taking into account the share of bond issues, the average yield growth was 1.45%. Considering the expected yield of 7.00%, the difference in the return on investment is very significant: the increase in profitability amounted to 20.71% of the expected return.

It should be noted that in the future, the complete robotization of the sequence of actions described above when forming a bond investment portfolio will allow institutional and private investors to solve effectively a number of interrelated tasks with minimal time, in particular, the task of selecting potential investment instruments, the task of structuring an investment portfolio, as well as the task of choosing the optimal moment to open and close positions in bonds.

Conclusion

Based on the study outcomes, the following conclusions can be drawn:

1) the modified riding the yield curve strategy applied to short-term bonds can be used both in the conditions of the classical interest rate curve shape and in the case of a flat interest rate curve;

2) the proposed yield indicator for the holding period, which takes into account the accumulation and coupon yield payment as well as the transaction costs that are individual for each investor, is a more accurate and objective indicator compared to the traditional indicator of bond yield to maturity;

3) the joint use of the single transaction criterion in combination with the algorithm for calculating the average market spread allows investors to more correctly evaluate the level of market liquidity of bonds and more accurately calculate the liquidity risk compensation coefficient;

Table 5.

Comparative profitability analysis of selected bond issues[3]

# / item	Name of bond issue	Yield for the expected holding period (subject to bond holding until maturity), % per annum	Yield for the expected holding period (subject to sale on September 18, 2020), % per annum	Error, % per annum
1	FPK Garant–Invest–001R–03	9.90	10.77	+0.86
2	RSG–Finans–4–bob	10.94	12.75	+1.82

[3] Moscow Exchange MICEX-RTS (https://www.moex.com/ru/marketdata/bulletins/#/date=2020-09-18)

4) the proposed compensation coefficients (price risk compensation coefficient, liquidity risk compensation coefficient, transaction cost compensation coefficient and general compensation coefficient) make it possible not only to comprehensively characterize the level of risk inherent in bonds according to the selected criteria, but also allow us to structure the bond portfolio (for example, in inverse proportion to total compensation coefficients).

The algorithms designed in this research for the bond portfolio selection and their software applications can be embedded in robotized and semi-robotized trading terminals and investment applications for use by institutional and private investors. ■

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About the authors

Eugene A. Korobov

Head of Laboratory of IT in Economics, Saratov State University, 83 Astrakhanskaya Street, Saratov 410012, Russia;

E-mail: korobovea@yandex.ru

ORCID: 0000-0001-7198-5941

Yulia V. Semernina

Dr. Sci. (Econ.), Associate Professor;

Professor, Department of Finance and Banking, Socio-Economic Institute, Saratov State Technical University, 77 Polytechnicheskaya Street, Saratov 410054, Russia;

E-mail: ysemernina@yandex.ru

ORCID: 0000-0003-2098-795X

Alina S. Usmanova

Cand. Sci. (Econ.);

Associate Professor, Department of Finance and Banking, Socio-Economic Institute, Saratov State Technical University, 77 Polytechnicheskaya Street, Saratov 410054, Russia;

E-mail: alina.brosalova@yandex.ru

ORCID: 0000-0002-8488-0425

Kristina A. Odinokova

Lecturer, Department of Finance and Banking, Socio-Economic Institute, Saratov State Technical University, 77 Polytechnicheskaya Street, Saratov 410054, Russia;

E-mail: odinokova.kristina93@mail.ru

ORCID: 0000-0002-8191-1337