UKRAINE BOND MARKET: YIELD CURVE ANALYSIS

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Abstract. The state of the bond market can be described using yield to maturity (YTM) curvewhichis a graphical representation of the dependence between the YTM of bonds of equal credit quality and their duration. It is proposed to change the original system of YTM indicators to the system of principal components which are linear orthogonal combinations of initial indicators. The obtained principal components can be predicted. In turn, each point of the yield curve can be restored from the predicted values of the principal components.

Key words: bond market, price, yield, maturity, yield curve, principal component.

The bond market is an integral and backbone segment of the economic system. It serves simultaneously as an element of the money market and the capital market, thus it performs the functions of mobilizing and redistributing financial resources. Its development is crucial for sustainable economic growth of any country.

The main aim of the paper is to conduct the analysis of bond market yield curve and to determine its core components.

Any bond as an object in a multidimensional space can be described by the following vector:

B=(f_price, m_price, coupon, period, m_date), wheref_price – face price (the price at which the bond will be redeemed); m_price – market price; C – coupon yield for one coupon period; period – time period between coupon payments; m_date – maturity date.

Knowing the basic characteristics of a bond described above, one can calculate such characteristics, as current yield and yield to maturity. The current yield for a fixed coupon bond (current_y) determines the paid annual interest on the invested capital and does not take into account the exchange difference between the purchase and redemption price: current_y=C/m_price. Therefore, to compare operations with different bonds, it is more correct to use the yield to maturity indicator (ytm):

$$P + A = \sum_{i=1}^{m} \frac{C_i + N_i}{(1 + \text{ytm})^{\frac{t_i - t_0}{B}}}$$

P – clean price of the bond, A – bond accrued interest, C_i – value of the i-th coupon payment, N_i – the i-th payment of face value, t_i date of i-th payment, t_0 – the date on which the calculation is made, B - the number of days in a year (calculation base).

The state of the bond market can be described using yield to maturity curve or zero-coupon yield curve. The yield to maturity curve is a graphical representation of the dependence between the yield to maturity of bonds of equal credit quality and their maturity (or duration). Zero-coupon yield curve represents the dependence between the yield to maturity of zero-coupon bonds and their duration. The last curve describes the so-called temporary structure of interest rates in the market. The difference between the two curves appears in the so-called coupon effect. Basing on the opinion about the relative identity of these two curves, we will further investigate precisely the yield to maturity curve.

The task of modelling the yield curve can be divided into two stages:

Stage 1 – assessment of ytm levels for all possible maturity values according to available market data.

Stage 2 – analysis of the yield curve.

The implementation of the first stage is rather challenging task due to the lack of a sufficient number of bonds with different maturities (failure to comply with the "full market" condition) [1]. In order to circumvent this limitation, one can implement methods that are divided into two groups: static (parametric and non-parametric) and dynamic [2-4].

The second stage can be implemented using the principal component (PC) method. As a rule, rates of return for various maturities strongly correlate with each other. Therefore, the yield curve can be described using a small number of factors linearly related to the yields. In this case, the main advantage of the PC method is the ability to significantly reduce the dimension of the original set of variables without significant loss of information and thereby improve the interpretability of the obtained results.

It is proposed to change the original system of indicators ytm_1, ytm_2, … , ytm_m to the system of principal components F_1, F_2,…, F_p, $p<m$. It is strongly recommended previously to transform the initial indicators ytm_i to their growth rates x_i. According to the method, principal components are formed as linear orthogonal combinations of indicators x_i:

$$F_i = \sum_{j=1}^{m} a_{ij} x_j \,,\ \sum_{i=1}^{m} a_{ij}^2 = 1,\ \sum_{i=1}^{m} a_{ij} a_{ik} = 0 \text{ ,j,k=[1,p], j}\neq\text{k} \,. \quad (1)$$

The principal components are chosen in such a way that among all the possible linear combinations of the original normalized indicators, the first principal component F_1 has the greatest variance. The second principal component F_2 has the greatest variance among all the remaining linear combinations (1), uncorrelated with the first main component. The remaining principal components are selected in a similar way.

This paper is devoted to research of the Ukrainian government loan bonds with maturities in interval from two to ten years. Initial data represent yield to maturity of the last transaction of the day for time period 2017-2018. Fig. 1 represents yield's dynamics for different maturities.

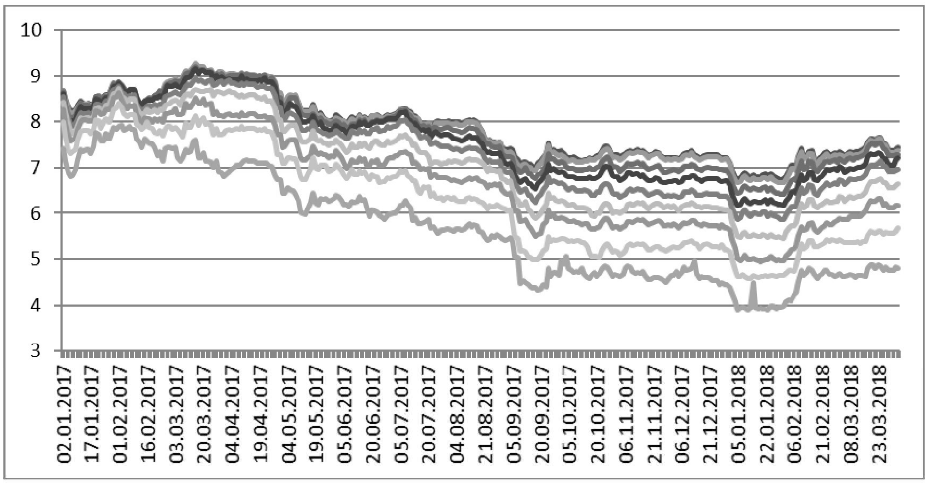

Fig. 1. Yield's dynamics for different maturities

The values of the pair correlation coefficients are presented in the Tab. 1. Fig. 1 indicates the presence of a close relationship between the indicators. This is confirmed by the results presented in the Table 1. Thus, we have strongly correlated data series of yields, which is a prerequisite for using the principal component method. Let's determine hidden unobservable variables that characterize the variability of the dynamics of these curves.

Table 1. Pair correlation coefficients

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
X_1	1,00	0,97	0,93	0,93	0,93	0,88	0,84	0,76	0,60
X_2	0,97	1,00	0,92	0,92	0,93	0,88	0,83	0,73	0,58
X_3	0,93	0,92	1,00	0,96	0,92	0,89	0,86	0,77	0,61
X_4	0,93	0,92	0,96	1,00	0,92	0,89	0,85	0,78	0,61
X_5	0,93	0,93	0,92	0,92	1,00	0,94	0,88	0,79	0,60
X_6	0,88	0,88	0,89	0,89	0,94	1,00	0,91	0,82	0,62
X_7	0,84	0,83	0,86	0,85	0,88	0,91	1,00	0,86	0,67
X_8	0,76	0,73	0,77	0,78	0,79	0,82	0,86	1,00	0,69
X_9	0,60	0,58	0,61	0,61	0,60	0,62	0,67	0,69	1,00

Initially, exactly nine principle components are allocated, the number of which corresponds to the number of initial indicators. The eigenvalues and the percentage of variance explained for the first three principal components are presented in the Table 2.

Table 2. First three principal components

	Eigenvalue	Total variance, %	Cumulative total variance, %
F_1	7,588983	84,32204	84,32204
F_2	0,631470	7,01633	91,33836
F_3	0,308183	3,42425	94,76262

According to the Table 2 the first principal component describes 84% of total variance and has the maximum eigenvalue. The second component and the third component characterize 7% and 3% respectively. In sum, the first three components account for about 95% of the total variation of the original data.

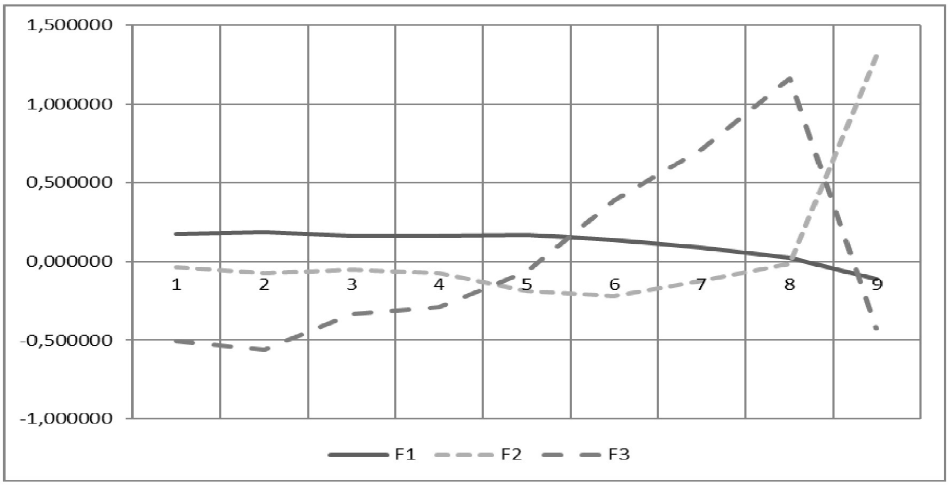

Fig. 2. Principal components of the yield curve

Fig. 2 shows graphical representation of obtained results. The first principal component (F_1) represents the level of the yield curve, the second component (F2) describes the slope and the third component (F_3) describes the curvature.

Thus, after transforming the original data set, its dimension was significantly reduced. However, no more than 5% of the initial information was lost. The obtained principal components can be predicted. In turn, each point of the yield curve can be restored from the predicted values of the principal components.

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