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FACTORS DETERMINING THE DEMAND FOR POLISH BONDS

Introduction

The aim of the paper was to investigate the changes in the demand for bonds on the Polish market. Based upon the previous research[1] the author supposed that the demand for bonds could be linked with the changes in the interest rates term structure. In one of the previous study the author verified the reaction of the zero-coupon bonds characteristics (duration and convexity) to the changes in the short interest rate, given the term structure which is not flat. It appeared that the convexity of bonds offered at the Polish market is a desirable feature when the short rate inclines, but not when it declines (on condition that only bonds of short time to maturity are taken into account). Based upon these results the author decided to investigate the investors' behaviour and verify whether the changes in the short rate can cause the changes in the demand for bonds. The alternative hypothesis was that it is the stock-exchange market that the investigated behaviour originates from.

1. Motivation

The inspiration for the research was the article of Maccini, Moore and Schaller "*The Interest Rate, Learning and Inventory Investment*"[2]. The authors tried to verify whether the negative dependence between the inventories and real interest rate changes (which was not supported by the empirical studies) could be found taken into account the current regime

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[1] A. Kliber, *Properties of the Duration Vector in the Polish and German Bonds' Markets* (in press) – presented at the FindEcon Conference (Forecasting Financial Markets and Economic Decision-making) in Łódź, Łódź 2006.

[2] L. J. Maccini, B. J. Moore, H. Schaller, *The Interest Rate, Learning and Inventory Investment*, The American Economic Review, American Economic Association, Vol. 94, No. 5/2004, p. 1303-1327.

of real interest rate. They discovered that when the interest rate enters one of its regimes it remains there for quite a long time and behaves rather stable, showing only minor fluctuations around its level. Thus, the companies ignore these small fluctuations and change their inventories only when the interest rate changes its regime.

The same idea was the inspiration for this research. While observing the behaviour of interest rate of a given maturity one can suppose that the main changes in its level are subject to the changes of the regimes and the minor fluctuations are responsible for within-regimes volatility. Thus, the main investors would not adjust their portfolios together with any small change of interest rate but rather learn about the interest rate regimes and change the structure of their portfolios on condition that the interest rate regime would change.

In the literature one can find some interesting studies considering the demand for bonds. For instance, Fisher[3] introduced various models for indexed bonds and two types of demand for them, namely a hedging demand (related to the share of this good in the consumption basket) and a speculative demand (which tends to increase the demand for bonds indexed on the prices of goods expected to rise rapidly, given equal rates on all bonds). However, contrary to Fisher, we took into account only zero-coupon bonds. Another position worth noting is the paper of Romer[4] who analyses the bonds finance, concentrating himself on the question when it is desirable for both: government to issue, and for citizens to hold bonds, and whether the government should issue interest-bearing bonds. The effect of the increased supply of bonds on the interest rates was studied by Masson[5].

2. Methodology

It was assumed that the interest rates follow a *regime-switching* process. We use this methodology when the observations suggest that the investigated process is influenced by an unobserved random variable s_t^* indi-

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[3] S. Fisher, *The demand for Index Bonds*, The Journal of Political Economy, Vol. 83, No. 3/1975, p. 509-534.

[4] D. Romer, (1993) *Why Should Governments Issue Bonds?,* Journal of Money, Credit and Banking, Vol. 25, No. 2/1993, p. 163-175.

[5] P.R. Masson, *Structural Models of the Demand for Bonds and the Term Structure of Interest Rates*, Economica, New Series, Vol. 45, No. 180/1978, p. 509-534.

cating so called state or regime, the process was in at the date t. For example, if $s_t^* = 1$, it means, that the process is in the first regime[6]. The simplest time series model for a discrete-valued random variable is the one that takes advantage of a *Markov chain*.

Let s_t be a random variable that can take only an integer value from the set $\{1, 2, ..., N\}$. Let us suppose that the probability that s_t is equal to some particular value *j* depends on the past only through the most recent value s_{t-1}:

$$P\{s_t = j \mid s_{t-1} = i, s_{t-2} = k, ...\} = P\{s_t = j \mid s_{t-1} = i\} = p_{ij} \tag{1}$$

Such a process is called an *N*-state Markov chain with transition probabilities $\{p_{ij}\}_{i,j=1,2,...,N.}$, where the transition probability gives the probability that the chain moves to the state *j* on condition, that a period ago it was in the state *i*. Of course:

$$p_{i1} + p_{i2} + ... + p_{iN} = 1 \tag{2}$$

The transition probabilities are often presented in the form of so-called *transition matrix*:

$$P = \begin{bmatrix} p_{11} & p_{21} & \cdots & p_{N1} \\ p_{12} & p_{22} & \cdots & p_{N2} \\ \cdots & \cdots & \cdots & \cdots \\ p_{1N} & p_{2N} & \cdots & p_{NN} \end{bmatrix} \tag{3}$$

Let us suppose that the typical historical behaviour of the analysed time series can be described with a first-order autoregression:

$$y_t = c_1 + \phi\, y_{t-1} + \varepsilon_t, \; \varepsilon_t \sim N(0, \sigma_1^{\,2}) \tag{4}$$

and that this model is appropriate for the data ranging from $t = 1$ to some $t = t_0$. Let us further suppose that at $t = t_0$ there was a significant change in the average level of the series, so that its behaviour would be better described with the help of the following model:

$$y_t = c_2 + \phi\, y_{t-1} + \varepsilon_t, \;\; \varepsilon_t \sim N(0, \sigma_2^{\,2}) \tag{5}$$

[6] J.D. Hamilton, *Regime-Switching Models,* working paper prepared for *Palgrave Dictionary of Economics,* 2005.

If the change were not deterministic, we can describe the behaviour of the process using more general model, namely:

$$y_t = c_{S_t} + \phi\, y_{t-1} + \varepsilon_t \qquad (6)$$

where s_t is a random variable denoting the regime in which the time series was at a given date (here: s_t=1 for t = 1,…, t_0 and s_t=2 for $t > t_0$). The probability of changing the state is given by the equation (1). Since we do not observe the s_t directly, we need the following parameters to describe the probability law governing y_t: the variances of the Gaussian innovations $\sigma_1^{\ 2}, \sigma_2^2$, the autoregressive coefficient ϕ, the two intercepts: c_1, c_2 and the two states probabilities: p_{11}, p_{12}. In other words: we observe the y_t directly but can only make an inference about the value of s_t based upon the past history of y_t. This inference takes the form of two probabilities (assuming, that there appear only two states):

$$\xi_{jt} = P(s_t = j \mid \Omega_t; \boldsymbol{\theta}) \qquad (7)$$

where: $j = \{1,2\}$, $\Omega_t = \{y_t, y_{t-1}, ..., y_0\}$, $\boldsymbol{\theta} = (\sigma_1, \sigma_2, \phi, c_1, c_2, p_{11}, p_{22})'$. The inference is performed iteratively and in order to perform it one needs the conditional densities under the two regimes:

$$\eta_{jt} = f(y_t \mid s_t = j, \Omega_{t-1}; \boldsymbol{\theta}) = \frac{1}{\sqrt{2\pi}\sigma_j} \exp\{-\frac{(y_t - c_j - \phi\, y_{t-1})^2}{2\sigma_j^{\ 2}}\} \qquad (8)$$

Given the input (8) we can calculate the conditional density of the t-th observation from:

$$f(y_t \mid \Omega_{t-1}; \boldsymbol{\theta}) = \sum_{i=1}^{2}\sum_{j=1}^{2} p_{ij}\xi_{i,t-1}\eta_{jt} \qquad (9)$$

and then:

$$\xi_{jt} = \frac{\sum_{i=1}^{2} p_{ij}\xi_{i,t-1}\eta_{jt}}{f(y_t \mid \Omega_{t-1}; \boldsymbol{\theta})} \qquad (10)$$

After executing these iterations one is able to evaluate the conditional log likelihood function of the observed data. Interested reader can find more details concerning the computation and algorithms for example in Hamilton[7].

[7] J.D. Hamilton, *Time Series Analysis*, Princeton University Press, 1994.

Dependent mixture models

A special case of these processes, that we will take advantage of, is known as i.i.d. *mixture distributions*. Again, we assume that the regime in which a given process is at the date t is indexed by an unobservable variable s_t where there are given N possible regimes (in our case N=2). When the process is in regime 1 we assume that the observed variable y_t has been drawn from a $N(\mu_1, \sigma_1)$ distribution, while when it is in regime 2 – from a $N(\mu_2, \sigma_2)$ one. Hence, the density of y_t, conditional on the random variable s_t taking on the value j is given by:

$$, \qquad \eta_{jt}{}^{m} = f(y_t \mid s_t = j; \boldsymbol{\theta}^m) = \frac{1}{\sqrt{2\pi}\sigma_j} \exp\{-\frac{(y_t - \mu_j)^2}{2\sigma_j{}^2}\} \qquad (11)$$

for j = 1,2. Here we denote by $\boldsymbol{\theta}^m$ a vector of population parameters (analogous to the vector $\boldsymbol{\theta}$) that includes $\mu_1, \mu_2, \sigma_1, \sigma_2$. The unobserved regime $\{s_t\}$ is presumed to be generated by some probability distribution for which the unconditional probability that s_t takes on the value j is denoted $\xi_j = P(s_t = j; \boldsymbol{\theta}^m)$. Thus, $\boldsymbol{\theta}^{\mathbf{m}} = (\mu_1, \mu_2, \sigma_1^2, \sigma_2^2, \xi_1, \xi_2)$. Given the equation (11) and the values of unconditional probabilities it is possible to compute the so called join density distribution of y_t and s_t:

$$f_{Y,S}(y_t, s_t = j, \theta^m) = f(y_t \mid s_t = j, \theta^m) P(s_t = j; \theta^m) = \frac{\xi_j}{\sqrt{2\pi}\sigma_j} \exp\left\{\frac{-(y_t - \mu_j)^2}{2\sigma_j^2}\right\} \qquad (12)$$

Thus, the unconditional density of y_t can be found by summing (12) over all possible values of j (here: j = 1,2):

$$f_Y(y; \boldsymbol{\theta}) = \sum_{j=1}^{2} f_{Y,S}(y_t, s_t = j; \boldsymbol{\theta}^m) \qquad (13)$$

If the regime variable s_t is distributed i.i.d across different dates t, then the log likelihood function for the observed data can be calculated from (13) as:

$$\mathcal{L}(\boldsymbol{\theta}) = \sum_{t=1}^{T} \log f_Y(y_t; \boldsymbol{\theta}^m) \qquad (14)$$

For further details see Hamilton[8].

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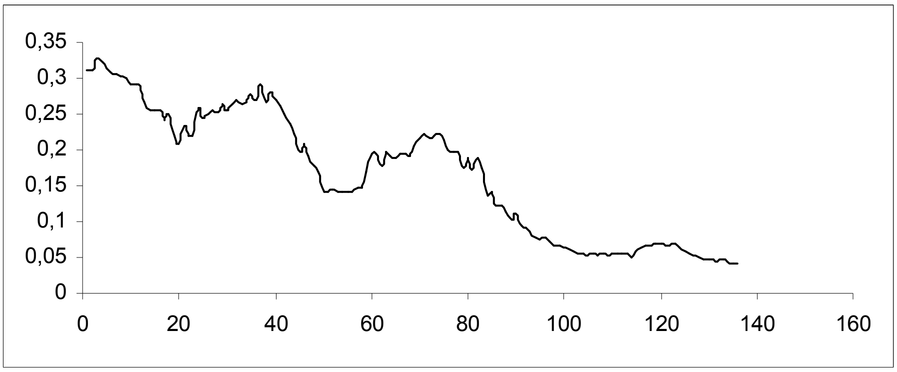
[8] Ibidem.

The dependent mixture models were used in our study to model the behaviour of the time series. For simplicity it was assumed that there appear only two states in all of the modelled processes. The first step was to estimate the process and deduce the states it was in at a given period. The states were introduced into the simple regression model for the demand for bonds. Next, it was verified whether the change in the state could determine the change in the demand for bonds on the Polish market.

3. The data

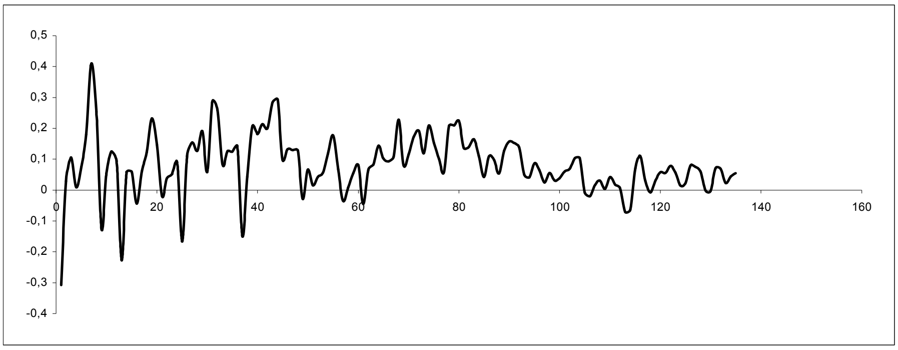
As a short interest rate the T/N WIBOR (tomorrow-next Warsaw Inter-Bank Interest Rate) was chosen. The picture below presents its variability across the period of January 1995-March 2006.

Figure 1. Monthly WIBOR T/N in the period: January 1995 – March 2006



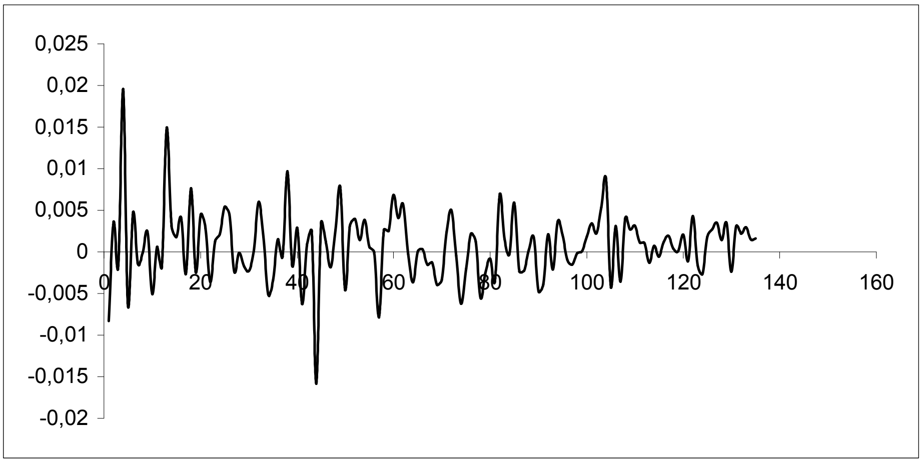
While observing the character of changes in the T/N WIBOR rate one can clearly see that it declines over time. Due to the hypothesis that this negative trend is caused mainly by the inflation, we removed the inflation component from the series. The real T/N WIBOR rate is presented on the picture below. It is clear that the sharpest changes occurred at the beginning of the observation period, while at the end they were rather smooth.

Figure 2. Monthly real WIBOR T/N in the period: January 1995 - - March 2006



In order to investigate the dependence between the bond market and the stock exchange we took WIG (Warsaw Stock Exchange Index) quotation into account. The picture below presents its percentage changes over the mentioned period. The percentage changes were first transformed into yearly effective rates and then the average monthly changes were computed.

Figure 3. Monthly changes of the WIG index



The data about the results of T-bonds and T-bills auctions were taken from the Polish Ministry of Finance's site. The instruments taken into the research were the treasury bills of maturity: 8 weeks (data ranged from January 1995 to October 2001), 13 weeks (January 2005 – January

2006), 26 weeks (January 1995 – January 2004), 39 weeks (January 1995 – February 2002), 52 weeks, as well as treasury bonds of maturity 1 year (both series ranged from January 1995 to March 2006) and T-bonds of maturity 10 years (May 1999 – January 2006). There were also a few examples of the "unusual T-bills" of maturity 7, 14, 21, 42 and 70 days. Since some days of issue for various kinds of instruments overlapped, we decided to order them in time, but keeping at the same time the information about their maturity. Thus, some moments in time could be doubled. Since in our analysis we do not take time into account, we believe that this way of arranging data does not cause any disruption.

4. Empirical study

4.1. Regimes estimation

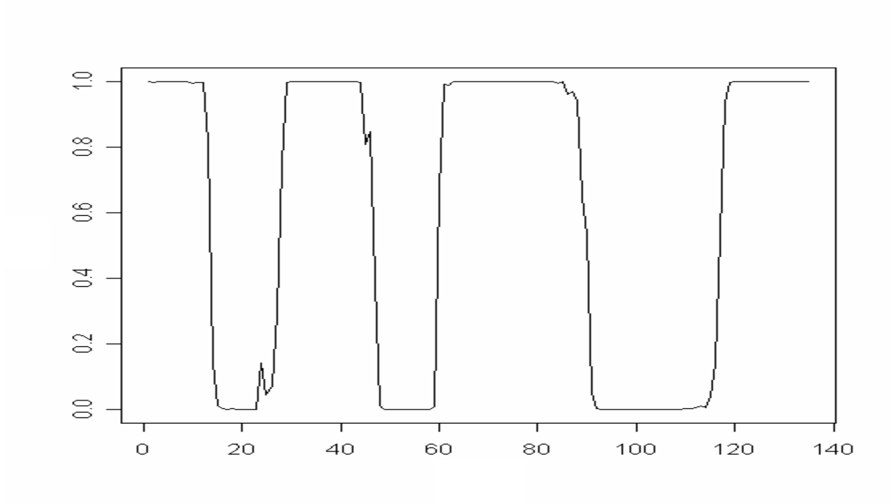
In the first step we estimated the regimes of the real interest rate and WIG changes. Since the WIBOR T/N time series had a trend, we did not estimate the model for this data, but only for the deviation from the trend. The estimation of the regime-switching model for the de-trended WIBOR gave the following results. The first regime was connected with the deviation from trend in minus (mean value: 3.21%, standard error: 0.205%) and the standard deviation: 1.471% (std. error: 0.168%), while the second – to the deviation in plus (mean value: 2.16%, standard error: 0.252%, std. deviation: 1.939%, std. error: 0.168%). The estimated transition matrix was as follows:

$$P = \begin{bmatrix} 0.945 & 0.055 \\ 0.038 & 0.962 \end{bmatrix}$$

The probabilities that the process remains in its lower regime are plotted at the figure below.

We also run the adequate estimation for the real WIBOR. The first regime was again associated with the lower value of the series and the mean value of the time series remaining in this regime amounted to 2.873% (standard error: 1.03%) with very high standard deviation: 7.341 (std. error: 0.577%), while the mean value in the higher regime was equal to 16.273% (standard error: 1.201%) with standard deviation: 6.740% (std. error: 0.605%). The transition matrix took the following form:

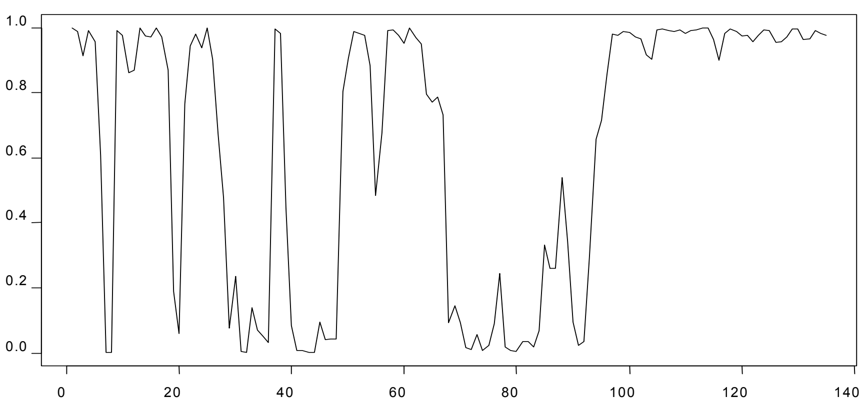
Figure 4. Probability of staying in the low regime in case of de-trended WIBOR



$$P = \begin{bmatrix} 0.932 & 0.068 \\ 0.100 & 0.900 \end{bmatrix}$$

The picture below presents the probability of remaining in the low regime.

Figure 5. Probability of staying in the low regime in case of real WIBOR

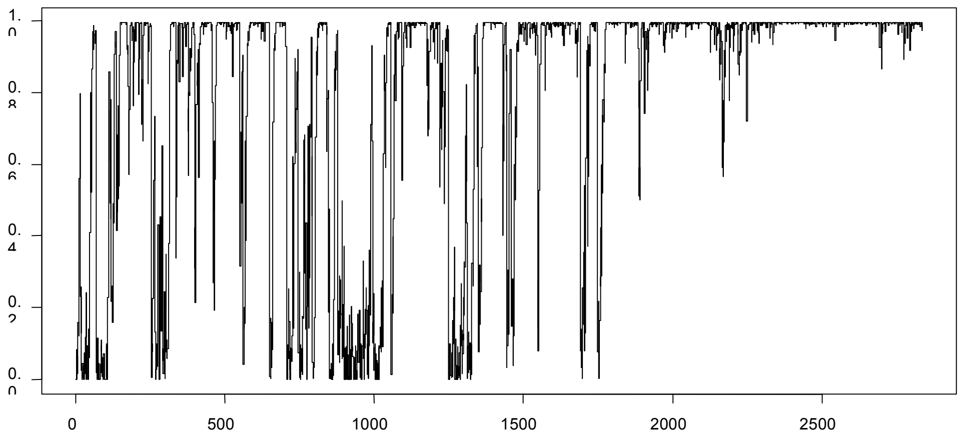


Eventually the WIG time series was analysed. It appeared that in the low regime the mean value of the series amounted to 0.06% (standard error: 0.027) and the standard deviation to 1.151 (standard error: 0.018), while in the high one –mean value to 0.185% (standard error: 0.113) and the standard deviation to 2.624 (std. error: 0.118). The transition matrix for the process was as follows:

$$P = \begin{bmatrix} 0.988 & 0.012 \\ 0.046 & 0.954 \end{bmatrix}$$

The probabilities of remaining in the lower regime are presented at the figure below (since we did not transform the data from nominal to real, there was no counter-indications to estimate the process for the daily data).

Figure 6. Probability of staying in the low regime in case of WIG



4.2. Definition of the demand

In the next step we defined the demand for bonds. The available data consisted of information about the demand, supply and the sold quality. First the author took the following convention. If the sold quantity was higher than the supply[9], we assumed that the supply was equal to the sold quantity. Eventually the effective demand was computed as a ratio of the sold quantity to the supply. Such a transformation was necessary to avoid the misleading results, since not always the same quantity of bonds was issued. However, as this transformation did not allow for drawing any clear conclusions the author decided to identify the demand with the sold quantity and add to the explanatory variables both – demand and supply.

4.3. Verification of the hypotheses

The first hypothesis stated that the quantity of the sold bonds can depend on the regime, the short interest rate was in (or more exactly – with the situation when the interest rate deviated from the trend in minus or in plus). Additionally, the author decided to analyse not only the nominal changes in the interest rate, but also the real changes. The second hypothesis that was verified stated that the changes of the demand originate from the stock-exchange market and thus it was tested whether the regime, the WIG was in, could affect the demand for the zero-coupon bonds.

Since the changes of WIG index were not very spectacular, as well as the changes in the short interest rate, we decided to take advantage of another type of interest rates, namely the Lombard, re-discount and reference ones. These are the Central Bank interest rates. One can easily deduce – even from the plot (see Figure 7) – that the changes of the interbank interest rates are connected with the changes of these three rates:

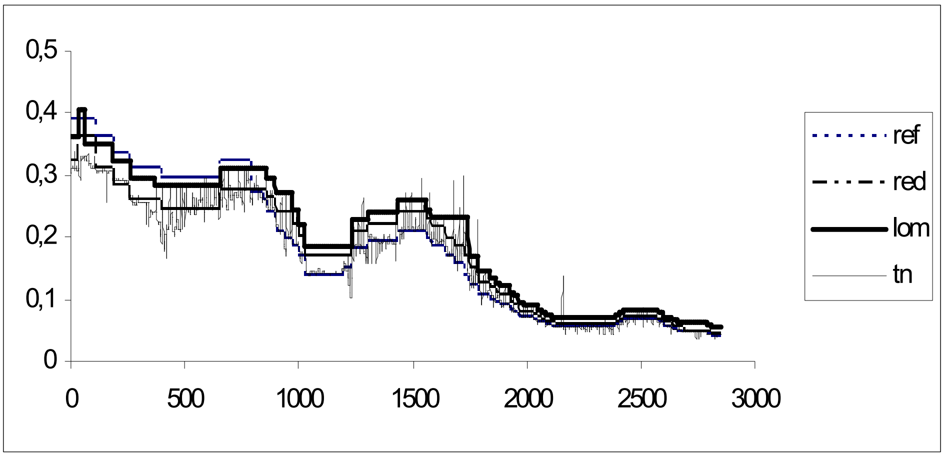
One may thus suppose that the regimes of the interest rates (here we consider only the tomorrow-next one) are set by the Central Bank interest rates. If the demand for bonds were very volatile and prone to interest rate changes, then the two regimes would not be able to capture the character of its changes. Moreover, taking only the deviation from the trend we may loose some important information, which would be included in the trend. That is why we decided to take into account also this type of interest rate regimes.

To summarise – we aimed at the explanation of the demand for bonds understood as the quality sold. The set of explanatory variables

[9] The exact regulations concerning the treasury bonds issue can be found in the draft of Minister of Finance regulation from 26.10.2006.

consisted of the following regressors: supply, demand, maturity of the bond, the Central Bank rate (i.e. the regime of the short interest rate set by the Central Bank rate), the regime of WIG, the regime of de-trended short interest rate and the regime of real interest rate. The regimes of the time series modelled as Markov-switching processes were included into the model as dummy variables, where the high regime was identified with 1, while the low one – with 0. Thus we analysed the reaction of the demand to the situation of entering and remaining in higher regime.

Figure 7. TN/WIBOR and the Central Bank rates



Note: ref – the reference rate, red – the rediscount rate, lom – the Lombard rate, tn – WIBOR T/N)

In order to choose the best subset of these variables we conducted the stepwise regression (see the Appendix for details). First we verified whether all of the mentioned variables played significant role in explaining the variability of the demand for bonds. It appeared that in all the cases one had to reject the null hypothesis about the lack of influence of the single variable to explanation the changes of the demand. However, as one could expect, the most significant one proved to be the supply. The procedure was continued in the following way – in each step a new variable from the set was added to the equation and its significance was checked, as well as the significance of all the explanatory variables together (the Fisher-Snedecor test). Eventually, we ended up with the following model:

$$Q_s = 9.459 + 0.093S + 0.801D - 1.144M - 13.348WIBOR_{real}$$
$$(5.517)\ (0.004)\ (0.15)\ \ (0.185)\ (4.706)$$

where:
Q_s – quality sold,
S – supply,
D – demand,
M – maturity,
$WIBOR_{real}$ – the dummy variable indicating whether the real WIBOR was in its high regime or not.
The numbers in parentheses denote the standard errors.

Another model which also fitted the data well was the one in which the regimes set by the Lombard rate were taken into account. However, the F statistic was lower for this model (F=4.6, while for the previous one: F=8.003):

$$Q_s = 19.913 + 0.090S + 0.799D - 1.079M - 67.733L$$
$$(9.575)\ (0.005)\ (0.015)\ (0.192)\ (31.515)$$

where:
L – Lombard rate.

Conclusions

The presented research aimed at the investigation of the demand for Polish zero-coupon bonds. It was verified whether the demand can depend upon the changes in the short interest rate – so we would be able to conclude that it is the interbank market that originate the changes in the investors' demand. The second hypothesis stated that the investors react not to the changes on the interbank market but rather to the changes on the stock exchange and that is why also the WIG variability was taken into account. Estimation of the regimes in which these time series were during the period: January 95 – March 2006 did not give very spectacular results. We had decided to estimate only two regimes: the one with high value of series' mean and the one with low value of this characteristic, to simplify the computation and interpretation. It appeared that the investors react to the incline of the real short interest rate by reducing their bonds' purchases. Similar results could be obtained if we take into account the regimes of interest rates set by the Central Bank rates.

To summarise, the research revealed that the effective demand for bonds (i.e. the quality of bonds which was really sold) depends on the initial demand, the supply and on the regime of the real interest rate or nominal interest rate set by the Lombard rate. It was also proven that the demand is negatively correlated with the time to maturity of the bond, i.e. the most preferred ones should be those of the shortest time to maturity. The demand was also negatively correlated with the changes in the Lombard rate, as well as with the situation of real interest rate approaching its high regime. We can thus say that when the real interest rates increases, the demand for bonds decreases. In other words, if the real interbank rates decline, the people chose to buy bonds instead of locating their money in the bank. As they do not want to freeze their money in the long-term investment, they prefer the bonds with the lowest possible maturity, which are more liquid.

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Rozporządzenie Ministra Finansów w sprawie warunków emitowania obligacji skarbowych uprawniających do określonych świadczeń niepieniężnych – a draft version from 26.10.2006.

Appendix

Table 1. Results of the first iteration of stepwise regression

Model no.	1	2	3	4	5	6	7
Regressor	demand	supply	maturity	Lombard rate	WIG	Real WI-BOR	De-trended WIBOR
Estimates	0.295	0.980	11.503	-1672.12	59.504	-70.571	-47.995
Error	0.005	0.009	0.366	85.537	20.593	16.909	17.184
t-value	59.655	**107.772**	31.456	-19.549	2.889	-4.174	-2.793
R^2	0.727	0.89	0.426	0.223	0.006	0.013	0.006

Note: All of the models were estimated with intercept, but for clarity we do not include them into table

Table 2. Results of the second iteration of the stepwise regression

Model no.	1			2		
Regressors	demand	supply	intercept	demand	maturity	intercept
Estimates	0.762	0.09	-17.128	-0.663	1.008	-9.945
Error	0.013	0.004	3.748	0.219	0.013	5.653
t-value	57.657	20.659		-3.028	78.402	
R^2	0.922			0.898		
F statistic	**323.532** > 3.848			9.115 > 3.848		

Note: We present only the results for the two most significant models

Table 3. Results of the third iteration of the stepwise regression (1)

Model no.	1				2			
Regressors	L. rate	demand	supply	intercept	WIG	demand	supply	intercept
Estiamtes	-98.817	0.76	0.087	9.12	3.245	0.761	0.09	-19.543
Error	31.498	0.013	0.005	9.487	5.792	0.013	0.004	5.713
t-value	-3.01	57.66	18.77		0.560	57.549	20.654	
R2	0.922				0.922			
F statistic	9.007 > 3.848				0.314 < 3.848			

Table 4. Results of the third iteration of the stepwise regression (2)

Model no.	3				4			
Regressors	real WIBOR	demand	supply	intercept	De-tr. WIBOR	demand	supply	intercept
Estiamtes	-13.218	0.761	0.090	-10.015	-1.525	0.762	0.091	-16.176
Error	4.768	0.013	0.004	4.535	4.832	0.013	0.004	4.813
t-value	-2.77	57.74	20.57		0.316	57.599	20.643	
R2	0.922				0.922			
F statistic	7.646 > 3.848				0.1 < 3.848			

Table 5. Results of the third iteration of the stepwise regression (3)

Model no.	5			
Regressors	maturity	demand	supply	intercept
Estimates	-1.142	0.802	0.094	2.233
Error	0.190	0.015	0.004	4.906
t-value	-6.001	54.732	21.489	
R2	0.924			
F statistic	**35.173** > 3.848			

Table 6. Results of the fourth iteration of the stepwise regression (1)

Model no.	1				
Regressors	Lombard rate	maturity	demand	supply	intercept
Estimates	-67.732	-1.079	0.799	0.091	19.9
Error	31.515	0.192	0.015	0.005	9.575
t-value	-2.149	-5.617	54.266	16.641	
R^2	0.924				
F statistic	4.607 > 3.848				

Table 7. Results of the fourth iteration of the stepwise regression (2)

Model no.	2				
Regressors	WIG	maturity	demand	supply	intercept
Estimates	3.044	-1.141	0.801	0.094	-0.042
Error	5.718	0.19	0.015	0.004	6.51
t-value	0.532	-6.00	54.637	21.484	
R^2	0.924				
F statistic	0.283 < 3.848				

Table 8. Results of the fourth iteration of the stepwise regression (3)

Model no.	3				
Regressors	real WIBOR	maturity	demand	supply	intercept
Estimates	-13.348	-1.144	0.801	0.094	9.459
Error	4.706	0.19	0.015	0.004	5.517
t-value	-2.836	-6.037	54.828	21.403	
R^2	0.924				
F statistic	**8.00** > 3.848				

Table 9. Results of the fourth iteration of the stepwise regression (4)

Model no.	4				
Regressors	De-tr. WIBOR	maturity	demand	supply	intercept
Estimates	-1.229	-1.141	0.802	0.094	2.992
Error	4.770	0.19	0.015	0.004	5.724
t-value	-0.258	-6.00	54.675	21.474	
R^2	0.924				
F statistic	0.066 < 3.848				