FACTORS AFFECTING T-BOND PRICES: FROM INVESTORS PERSPECTIVE

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Abstract

The purpose of the paper is to describe the motives attracting portfolio investors to the Polish treasury paper market and to offer some empirical results showing the relative importance of the factors affecting bond prices. Empirical results prove important relationship between the bond market (represented by bond prices or market optimism index) and the short term interest rates, the behavior of the exchange rate of the zloty and the budget deficit. The models estimated for the purposes of the paper offer results, which may be helpful both for investors and policy makers.

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1. Introduction

The main factor attracting foreign investors to emerging countries' bond markets are high yields and relatively low correlation with their core holdings. Both factors enhance investors' overall Sharpe ratio[3]. In case of Poland there are two additional factors attracting foreign investors. The first is the opportunity of the "convergence play". The second is the liquidity of the Polish bond market.

In literature there were investigated a number of topics that focused on the issue how to price risk for emerging markets. Dym (1997) describes three major categories of risk that should be applied for bond valuation: liquidity risk, credit risk and the influence the various structural factors determining the general social and economic health of a country. As a result he proposes a premium (spread) over the U.S. T-bond yields. Also Cantor and Packer (1995) focused on macroeconomic factors explaining spreads. Their research covered GDP, inflation, budget balance, external debt, current account, and the credit rating of a country. Eichengreen and Moody (2000) suggest more possible factors explaining spreads (especially launch spreads). Apart from fundamentals, their research covers changes in policies of financial institutions (financial liberalization tends to narrow spreads). Additionally, they research price behavior in emerging bond markets. They analyze propensity to issue bonds by regions. They find that when the U.S. yields are high the volume of new bond issues in emerging markets decreases. This tends to narrow spreads. The relation was defined as *demand side effect*, which is characteristic for East Asian countries. The opposite relation, which tends to widen the spreads, was defined as *supply effect*. The relation is characteristic for Latin America and Eastern European countries, where portfolio capital inflow is one of the sources financing current account deficits (Lipschwitz, Lane, Mourmouras, 2002).

The research discussed above is focused on yield spreads over the U.S. Treasury paper. The goal of our research was to find specific relationships that exist in the Polish bond market. Of course, we take into consideration that the Polish bond market has

[3] *Quantitative Management of Bond Portfolios*, Lehman Brothers, Fixed Income Research, May 2000, p. 13.

become an integral part of the global bond market and the prices of Polish bonds reflect also the changes in international bond trading. Nonetheless, every market has its internal characteristics. Accordingly, our research focuses on identifying bond prices reactions to the NBP monetary policy, to the behavior of the zloty rate, and to the changes in the budget deficit.

2. Polish bond market

There are three main groups of foreign players in the Polish T-bond market: commercial banks, investment banks and long-term investment funds. The behavior of these three groups of players is determined largely by their investment horizon and the regulations imposed on their risk taking.

Commercial banks have short-term liabilities (in the form of deposits and short-term loans) and they are highly regulated. With short-term liabilities they do not hold large *investment* (long-term) portfolios of bonds. In most cases they hold mainly *trading* (short-term) portfolios of bonds in order to take short-term risk exposures in the OTC market.

International investment banks have also relatively short-term liabilities (in a form of funds borrowed in the money market and the commercial paper market). Due to their relatively short-term sources of funding, investment banks also do not hold large *investment* portfolios of bond. They also hold bonds in *trading* portfolios to take short-term exposures in the OTC market. However, investment banks are less strictly regulated than commercial banks. This allows them to take relatively more market (price) risk.

Due to their long experience and the related *know-how*, investment banks are engaged also in financial engineering, which enables them to sell structured products (e.g. credit derivatives). They offer also various kinds of financial services to long-term investors (e.g. custodian and settlements services).

Institutional investors are called *real money* in the language of financial markets, because they do not have to borrow short-term funds to finance their assets. Instead, they use *real money*, which flows to them in a form of contributions as in the case of pension funds and insurance companies. With long-term liabilities *real money* exercise “buy and hold” strategy. They buy bonds to their *investment* (long-term) portfolios. Thus, they take mainly credit (issuer insolvency) risk. They do not take much market (price) risk, because they are highly regulated.

There were the two major reasons making the Polish T-bond market attractive to *real money*. The first was a relatively low level of T-bond prices in relation to the actual credit risk. The second reason was the opportunity to take part in the *convergence play* in the T-bond market of a country, which is a prospect member of the EMU.

For banks the Polish bond market was attractive due to its liquidity and price volatility related to successive interest rate cuts, which were implemented along with the process of disinflation.

From the point of view of a foreign investor, liquidity of a given emerging market may be measured by price reactions to the flows of portfolio capital. From this point of view the Polish bond market has become much safer during the last few years. The risk that unwinding of an investment in Poland might lead to a substantial fall in the bond prices has significantly decreased.

Liquidity of the Polish T-bond market improved substantially due to the liberalization of forward transactions by the end of 1998. This phase of capital flows liberalization enabled the rapid growth of foreign exchange swap market for the Polish zloty and accelerated the development of the London swap market for the Polish interest rates.

Foreign exchange swaps are in fact synthetic zloty deposits. Accordingly, the development of the *fx swap* market opened for investors an easy access to the short-term funding in zlotys. Due to the development of the IRS market investors could easily manage the interest rate risk taken in the Polish T-bond market. The factor, which added to the liquidity of the T-bond market, was the development of the asset swap market, which was also enabled by the liberalization of forward transactions.

The improved liquidity of the T-bond market in Poland was illustrated by the bond price behavior in the first half of 2002, when the rise in bond prices (due to expected interest cuts) was not stopped by the substantial increase in their supply due to the higher budget deficit.

3. Empirical results[4]

The main factors influencing bond prices are the expected short-term interest rates and risk premiums related to the bond market liquidity risk, to the issuer credit risk and to the exchange rate risk, which is important for investors holding international bond portfolios (Huttman, 1998). The research presented in this paper focus on the impact, which is exerted on the bond prices by the expected interest rates, by the volatility of the zloty and the credit risk related to the changing volumes of the budget deficit. We also tried to capture the influence of the *sentiment* of the market, represented by the spread between the cost of short-term zloty financing and bond yields.

3.1 Methodological introduction

Empirical analysis is applied to estimate the strength of the dependence between the bond yields, the National Bank of Poland interest rates, *the exchange rate of the zloty*, the forward interest rates, the budget deficit and the current account balance. The research is focused to recognize the strength of the relationships, lag distribution and time allocation structure, existence of long run equilibrium and correction mechanism between current and long run balance. Individual variables are modeled in pairs. The purpose of the research was not to build multivariable or multiequation models, but to recognize direct relationships without possible intervariables netting effects.

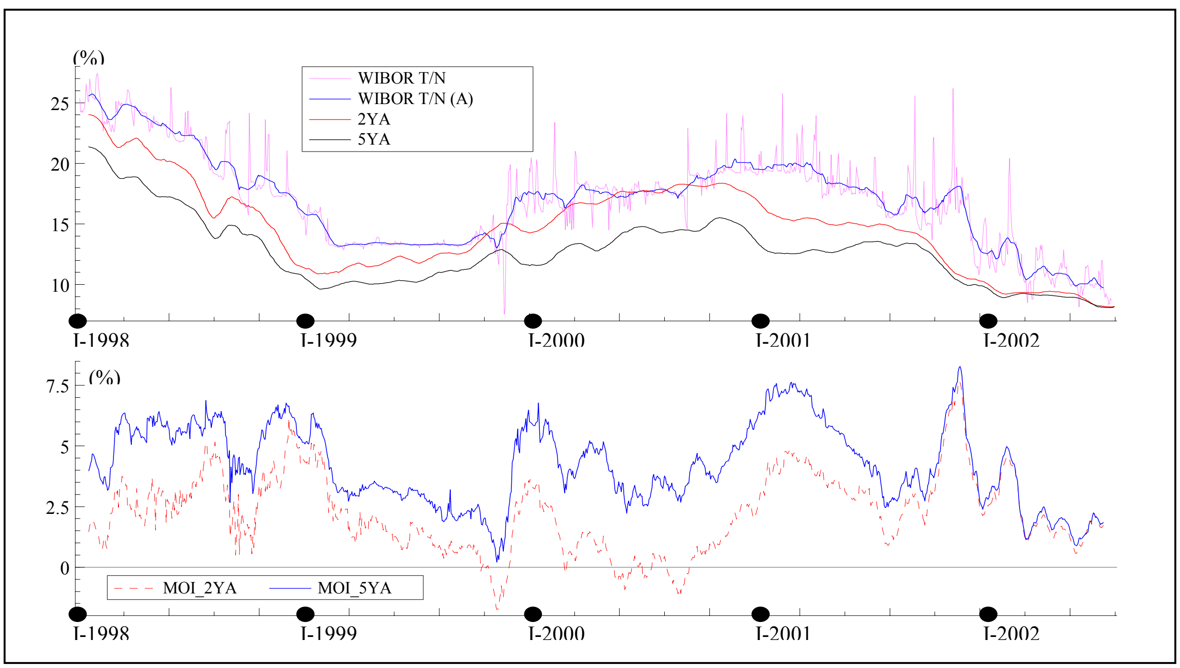
[4] The empirical results presented below represent about 20% of all quantitative analysis, which were done for preparing the paper.

The variables will be represented by:

(Y) – Nominal yield of bonds. If the analysis is for 2 or 5-year bonds then there will be used (2Y) and (5Y). For market optimism indicator (MOI) we took the difference between the averaged WIBOR T/N and the yields of bonds.
For further calculations we used different types of MOI indicators, for which we used the following notations:
A – centralized moving average for n=21 observations (current observation = median observation = 11th observation);
B – end-period moving average for n=21 observations (current time = last observation);
MOI (A) = WIBOR T/N (A) – Y;
MOI (B) = WIBOR T/N (B) – Y;
MOI (C) = WIBOR T/N (A) – Y(A);
WIBOR T/N (A) – WIBOR T/N centralized moving average for n=21 observations;
WIBOR T/N (B) – WIBOR T/N end-period moving average for n=21 observations;
Y(A) – bond yield centralized moving average for n=21 observations;
MOI (A), MOI(C) – for centralized moving average for n=21 observations;
MOI (B) – for end-period moving average for n=21 observations;

E.g.: $MOI\_5YA_t = \frac{1}{21}\sum_{i=-11}^{11} WIBOR\_T/N_{t+i} - 5Y_t$.

Exhibit 1
Interbank interest rate (WIBOR T/N), bond yields and market optimism indicator (for period: I 1998 – VI 2002; 1150 daily observations).



Source: Own analysis.

A simple analysis of MOI (see Exhibit 1) shows that since the third quarter of 2001 we have nearly no gap between MOI(2YA) and MOI(5YA). There is a strong convergence of yields for 2 and 5-year bonds.

Additionally the MOI can be related to the deviations of the Polish zloty rate from its former parity (basket) rate[5]. The model in the sub-section 3.3 shows that the MOI is affected by the changes of the zloty *basket* rate.

For the analysis of the exchange rate behavior we use two variables:

(PLN/USD) – Polish zloty and US dollar NBP exchange rate;

(Parity) – deviation of the Polish zloty rate from the basket rate; positive values assume appreciation of Polish currency.

Other variables:
(NBP) – National Bank of Poland reference interest rate (28-days interest rate);
(FRA) – FRA rate for 3x6 contracts;
(BD) – budget deficit in bn PLN; positive values assume surplus, negative – deficit;

The whole analysis covers period since January 1998 till end of June 2002. It gave us about 1150 daily or 54 monthly observations. However, some models will be estimated based on a few observations less due to a number of degrees of freedom (d.f.) or application of forward looking variables.

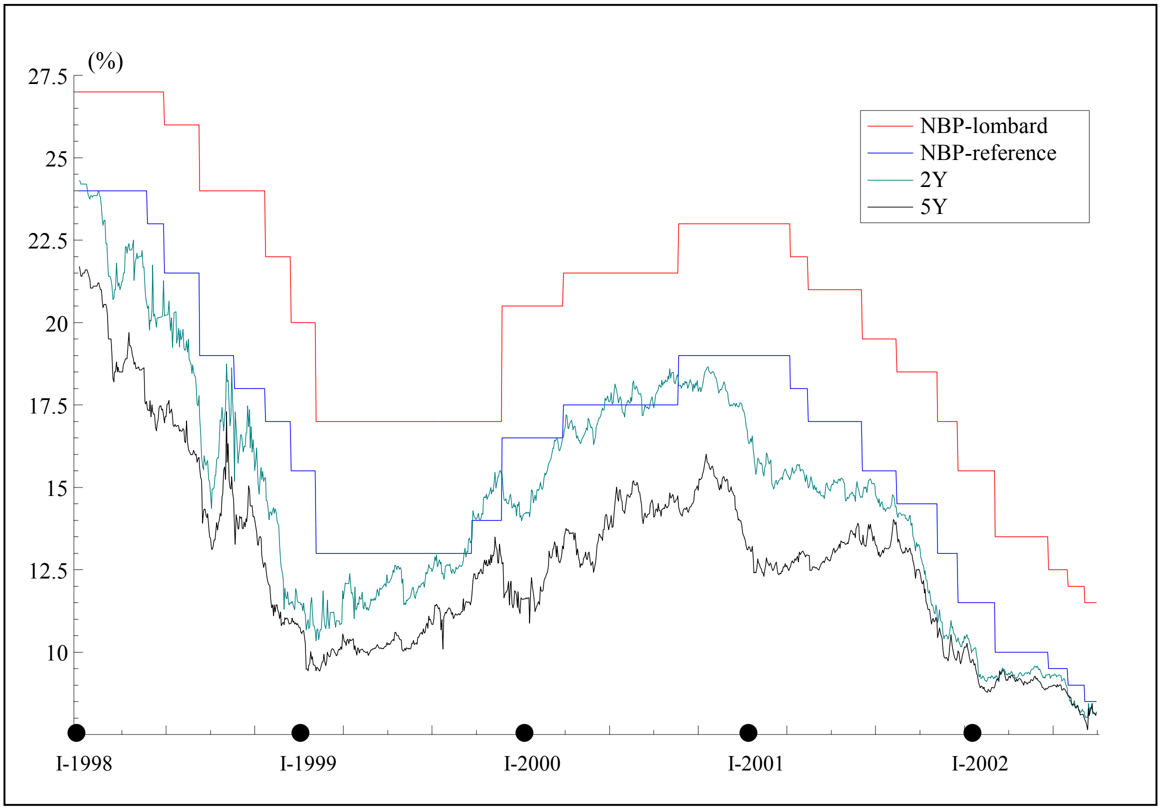
3.2 The NBP interest rates

The analysis below confirms that bond prices discount future NBP interest rates with a substantial precision. This pre-adjustment process can be modeled with the usage of the two different types of time series. It is possible to build models based on daily data. Such models may be useful for short-term decisions. It is also possible to estimate models based on monthly averages. These may be helpful for more strategic investment decisions.

[5] Using the *basket* rate eliminates the zloty fluctuations resulting from fluctuations of the EUR/USD rate.

Exhibit 2

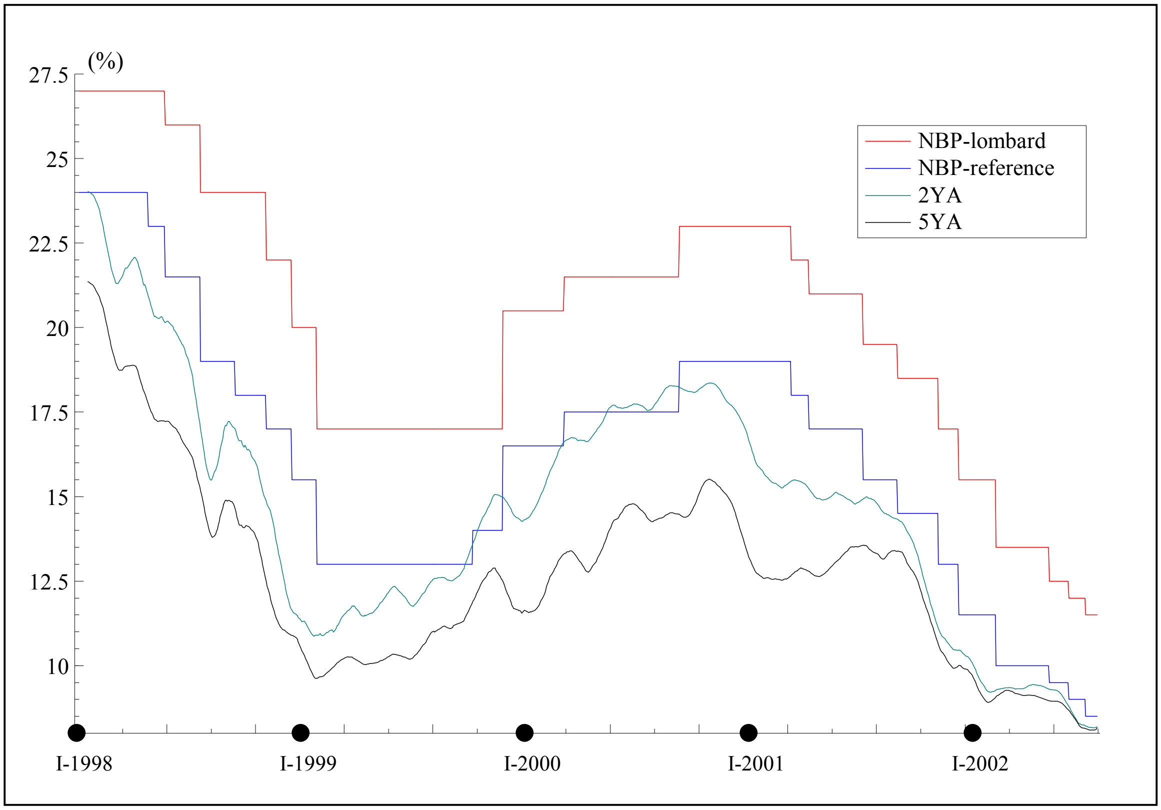
Lombard and reference interest rates of NBP, and bond yields (for period: I 1998 – VI 2002; 1150 daily observations).



Source: NBP; own analysis.

Even introductory graphical analysis (see Exhibit 2) suggests existence of statistical relationship between the NBP interest rates and bonds yields in Poland. Exhibit 2 illustrated two important phenomena. Firstly, there are similarities between the paths of bond yields and the shapes of the NBP interest rates (especially the path of 2-year bonds). Second, we can see some time displacement of those two paths. The graph shows that the market in advance price possible future NBP decisions.

Exhibit 3
Lombard and reference interest rates of NBP, and bond yields as moving averages (for period: I 1998 – VI 2002; 1140 daily observations).



Source: NBP; own analysis.

Econometric modeling is used here to find the relationship between bond yields and NBP interest rates. The first analysis was performed for daily time series (see Exhibit 2). It did not give strong results. However, there were obtained several statistically good models. The problem is that they produce some uncertainty for economic interpretation. It is mainly a result of ample daily price fluctuations in the bond market, while the NBP interest rates are fixed for long time intervals. Daily amplitudes of bond yields fluctuations are independent of NBP interest rates. This problem can be solved by application of moving averages[6] for bond yields. The transformed variables are presented at Exhibit 3. The econometric modeling of the corrected time series gives much better results than before.

The obtained models suggest that NBP interest rates are dependent variables and bond yields explanatory variables. Of course, in reality yields in the bond market are dependent on the future NBP interest rates.

Empirical results show that the reaction of bond prices to the expected change in NBP rate takes place more than one week (even up to 10 quotation days) before the expected change of the central bank intervention rate. This probably reflects the fact that a week before the meeting of the Monetary Policy Council (MPC) markets know the full set of the available data on the economy and are prepared for final assessment of the expected change in the NBP interest rate.

It is interesting that the market is quite precise[7] in its estimates. However, the adjustment process is not equally distributed over time. It has statistically significant compensative correction movements. Models based on daily data may be useful for market players involved in the daily trading. The models based on monthly data may be useful for longer-term investors. The best two monthly data models are presented in Table 1. In both cases we can see that bond yield is a second order autoregressive process AR(2) with an autocorrection[8]. However, both models suggest statistically significant role of future NBP rate for bond pricing. In the model (A) the reference rate is for upcoming month: (t+1), and in the second model (B) it is for the period (t+2). In practice it is possible to think that the optimal shift is between 1-2 months. E.g. greater forward looking do not give significant results.

[6] It is recommended to use n=21 observations centralised moving average. Then the current observation is a median (n=11) observation within a mean. 21 observations is also the best proxy for a monthly sub-periods. In average there are 21 observations (working days) per month within a year.

[7] Which is confirmed by the obtained equilibrium (ex-ante versus ex-post).

[8] The consecutive lags have different signs.

Table 1
Bond yields as a function of future NBP reference rate for period I 1998 – VI 2002.[9]

Model (A)
Modeling 5Y by OLS
The present sample is: 1998 (3) to 2002 (6)

Variable	Coefficient	Std.Error	t-value	t-prob	PartR^2
Constant	0.93728	0.39776	2.356	0.0226	0.1037
5Y_1	0.89927	0.13868	6.485	0.0000	0.4670
5Y_2	-0.29497	0.10635	-2.774	0.0079	0.1381
NBP+1	0.25188	0.055835	4.511	0.0000	0.2977

R^2 = 0.94962 F(3,48) = 301.59 [0.0000] \sigma = 0.568024 DW = 1.86
RSS = 15.48728495 for 4 variables and 52 observations

Model (B)
Modeling 5Y by OLS
The present sample is: 1998 (3) to 2002 (5)

Variable	Coefficient	Std.Error	t-value	t-prob	PartR^2
5Y_1	0.94416	0.14217	6.641	0.0000	0.4737
5Y_2	-0.22105	0.11305	-1.955	0.0563	0.0724
NBP+2	0.21609	0.048229	4.481	0.0000	0.2906

R^2 = 0.998002 \sigma = 0.586363 DW = 1.96
RSS = 16.84725832 for 3 variables and 52 observations

Notes: *5Y_1 = $5Y_{t-1}$, 5Y_2 = $5Y_{t-2}$, NBP+1 = NBP_{t+1}, NBP+2 = NBP_{t+2}.*
Variables $5Y_t$ and NBP_t are used as arithmetic averages for proper month (t).
NBP_t – National Bank of Poland reference rate.
Source: *Own analysis.*

The model (B) from Table 1 seems to be statistically more interesting. It will be utilized for the following analysis (see formula (1)).

$$5Y_t = 0{,}944 * 5Y_{t-1} - 0{,}221 * 5Y_{t-2} + 0{,}216 * NBP_{t+2} + e_t \,, \qquad (1)$$

The variable (NBP_{t+2}) says that within the medium-term tendency the current yield takes into account possible change of the NBP reference rate about 2 months before the actual

[9] Construction of similar models with logarithmic variables gives nearly the same output. However, logarithmic model has some better econometric properties. But on the other hand it is more sensitive. For more detailed selection there should be applied proper tests for a search of better functional form. Here it is omitted due to not significant differences generated by both models.

change of the rate. The formula (1) has a status of short-run or direct response function (the perspective of 1 month).

Further econometric analysis proves the existence of cointegration[10] between 5-year bond yields and the NBP reference rate. Existence of the cointegration means that it is possible to model a long-term relation between both variables. It has the status of long term equilibrium relationship. Its regression coefficient can be estimated by formula (2).

$$b = \frac{\sum_{j=0}^{q} \beta_j}{1 - \sum_{i=0}^{p} \alpha_i} = \frac{0,216}{1-(0,944-0,221)} = 0,78 . \qquad (2)$$

Finally the long-run relationship is:

$$5Y_t = 0,7804 * NBP_{t+2} + ECM_t \qquad (3)$$

This long-run equilibrium is also presented at Exhibit 4 (upper-right graph). The Wald test for the parameter (0,7804) from equation (3) gives positive result for any s.l. Using equation (3) we can estimate an error correction mechanism for estimated model (see also Exhibit 4 bottom-left graph). It is presented in equation (4).

$$\Delta\, 5Y_t = 0,014 + 0,310 * \Delta\, NBP_{t+2} - 0,305 * ECM_{t-1} \qquad (4)$$

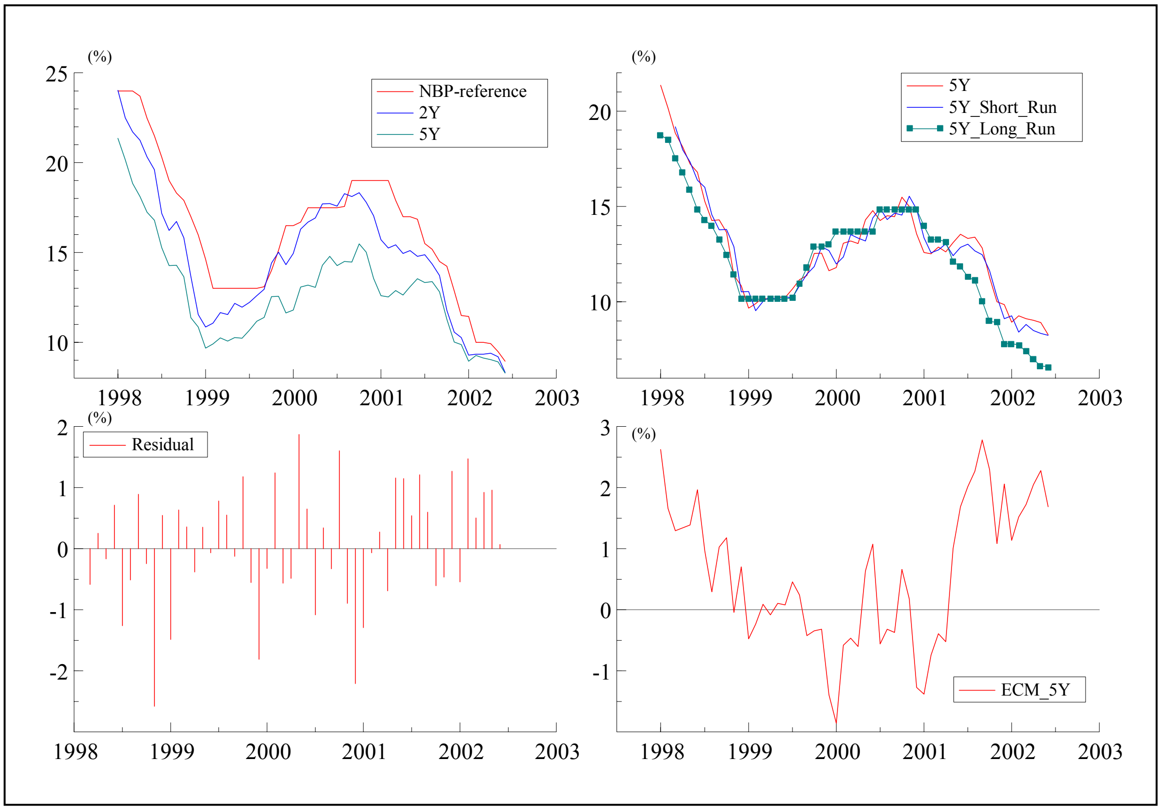
The equation (4) has significant parameters before variables (Δ NBP_{t+2}) and (ECM_{t-1}). The constant is not significant but is unimportant in this case.

The analysis of equations from (1) to (4) and the Exhibit 4 shows that both short and long-run functions are quite close to each other with only some discrepancies. It is better to analyse those discrepancies, as a difference between the observed variable and the long-run estimations. The difference is equal to the (ECM_5Y) in Exhibit 4. It has the tendency to oscillate around “zero”. This is a positive result that allows us to assume that the market has neither positive nor negative bias towards the expected NBP rates. Despite that there are situations when markets over-estimate or under-estimate the expected changes in NBP

[10] Proper integration ranks for variables were obtained at 10% s.l.

interest rate. The parameter (-0,305) at the (ECM_{t-1}) in the equation (4) informs us that the full correction of miss-estimation takes place on average more than 3 months[11]. However, more than 30% of the divergence (expressed by an error) is corrected within one month.

Exhibit 4
Reference interest rate, bond yields as monthly averages (for period: I 1998 – VI 2002; 54 monthly observations).



Source: Own analysis.

The largest divergence, expressed by an error term (ECM_5Y), has occurred since the 3rd quarter of 2001. It continued in 2002. This can be interpreted as a permanent and strong downward pressure for bonds yields. The model predicted this direction and size of change correctly.

[11] $n=(-\gamma)^{-1}$; that is here: $n = (-(-0,30501))^{-1} = 3,27858$ monthly periods.

The proposed model may be useful for investors, as it may help them to estimate whether bond are underpriced or overpriced. The evidence are the developments in the Polish bond market during the last few years.

The largest under-estimation of expectations on the size of the fall in T-bond yields occurred in the third quarter of 2001. Investors did not predict that in 3-4 months the yields would be 3% lower. Similar situation took place in the first quarter of 2002. The major reason for this under-estimation was the underestimate speed of disinflation.

The opposite situation took place at the beginning of 2001. Investors over-estimated the size of the expected cuts in NBP rate. The NBP monetary policy turned out to be more cautious than the markets expected. Similar situation occurred at the end of 1999 and the beginning of 2000. One reason for this was that investors could not predict precisely the moment of the floating of the zloty in April 2000, which increased the risk premium for Polish bonds. The other reason was that investors could not predict the acceleration of the fall of the euro against the dollar, which added to the nominal depreciation of the zloty.

3.3 The exchange rate of the zloty

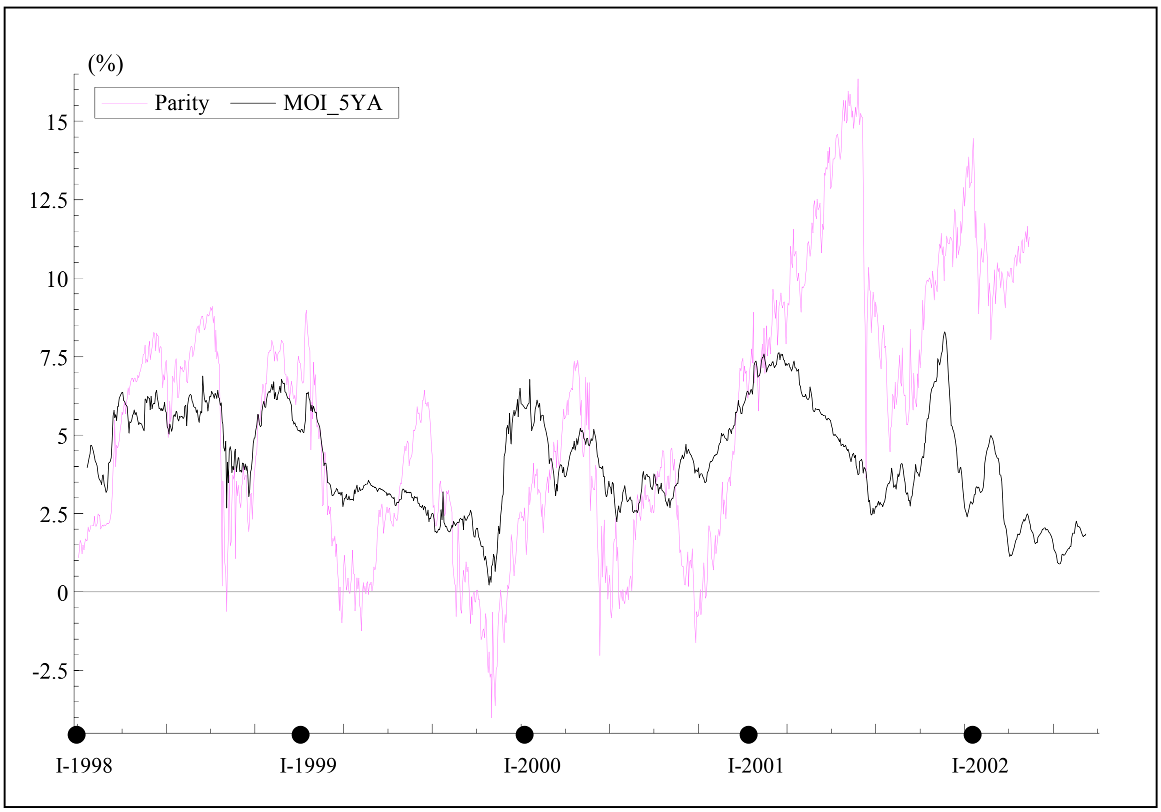
For the purpose of this paper we analyzed the relationship between the rate of the Polish zloty and the MOI (market optimism index). A simple analysis of this correlation produces results, which are inconsistent and chaotic. Some results can be even opposite to each other depending on the calculation method applied e.g.: the length of series, starting point, end point, or if the correlation is cumulative or for constant size sample moving over time. Such poor results pushed us to apply more sophisticated analytical tools.

3.3.1 MOI and the deviation of the zloty rate from its old parity

The first model analyzes the relationship between the market optimism indicator (MOI) and the deviation of the zloty rate from its old parity (see Exhibit 5). The initial analysis was based on daily observations. It did not offer any interesting results. The relationship was swamped by “noisy daily fluctuations”. We did not obtain acceptable models, but the cumulative total effect multiplier was always converging to zero. Significant far lags had tendency to compensate. Most far lags had self-corrective properties. The model was not improved by different methods of estimation or changes in specification for variables. Also shift in exogenous and endogenous variables was insignificant.

The usage of the daily observations produced serious bias for the models. However, when we changed the time horizon we improved the fit of models, which made them potentially useful for decision making purposes in the bond market.

Exhibit 5
Fx deviation from the NBP parity of currency basket; MOI for 5-year bonds (for period: I 1998 – VI 2002; daily observations).



Source: NBP data; own analysis.

Table 2
MOI as an autoregressive process also dependent on a change from the parity divergence.

```
Modeling MOI_5YA by OLS
The present sample is:  1998 (2) to 2002 (2)

Variable      Coefficient    Std.Error  t-value  t-prob PartR^2
Constant           1.4714      0.44822    3.283  0.0020  0.1898
MOI_5YA_1         0.65299     0.096002    6.802  0.0000  0.5014
DParity           0.23539     0.062164    3.787  0.0004  0.2376

R^2 = 0.59807  F(2,46) = 34.224 [0.0000]  \sigma = 0.953101  DW = 2.06
RSS = 41.78647916 for 3 variables and 49 observations
```

Notes: *MOI_5YA = MOI_5YA_t, MOI_5YA_1 = MOI_5YA_{t-1}, DParity = $\Delta Parity_t$.*
$\Delta Parity_t$ – Change in deviation of PLN from the NBP fx parity.
Source: Own analysis.

The estimations were done for 50 monthly observations[12]. The best model obtained is presented in Table 2. Despite R^2 = 60% the model has very good other statistical properties. The residuals are free from autocorrelation. They are homoscedastic and normally distributed. Other properties are also promising.

The model gave interesting results. The market optimism index (MOI_5YA) turned out to be dependent not only on its previous size but also on the *change* of the divergence of the zloty rate from its old parity (ΔParity)[13]. Thus, the size of the divergence from parity is not important, but the size and direction of change are important (see Table 2).

There can be also estimated a long run relation for the model in Table 2. The relation presented in Table 3 is significant at 5% s.l. The comparison of empirical observations, short run and long run relationships are presented at Exhibit 6 (middle graph). The difference between long run equilibrium and observed data can be written as error correction model (see Exhibit 6 - bottom graph). The exhibit for ECM shows a kind of frequent oscillation around zero. There are about 2,5 – 3 oscillations a year. Accordingly, one full cycle covers period of about 4-5 months. The cycles are repeatable. This suggests that market goes through “optimism – pessimism“ cyclical fluctuations and the cycle

[12] It is just enough to apply some general standards of testing without discussing small sample distribution properties.
[13] The nominal change of variable (X) is defined as: $DX_t = \Delta X_t = X_t - X_{t-1}$.

affects bond prices. The discounting of such a cycle may also be helpful in the decision making in the bond market.

Table 3
Long run relationship for the model presented in Table 3.

```
ECM_MOI_5YA / DParity [1998 (1) to 2002 (6)]

Solved Static Long Run equation
     MOI_5YA =     +4.24             +0.6783 DParity
(SE)          (   0.3976)          (    0.242)

ECM = MOI_5YA - 4.24031 - 0.678339*DParity;

WALD test Chi^2(1) = 7.8554 [0.0051] **
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Notes: $MOI\_5YA = MOI\_5YA_t$, $DParity = \Delta Parity_t$.
Source: Own analysis.

Expected value of ECM should be zero, if we would like to maintain the assumption of the long term neutrality of the foreign exchange rate. Here the mean for ECM is equal +0,10% and is very close to zero (compared with its range from –2,5% up to 2,5%). That allows us to assume that there is a long-term equilibrium for MOI and the divergence of the zloty from its parity rate. The periods of disequilibrium states are probably caused by “optimism cycles” and other shot-term factors.

Table 4
Error Correction Model for the model presented in Table 3.

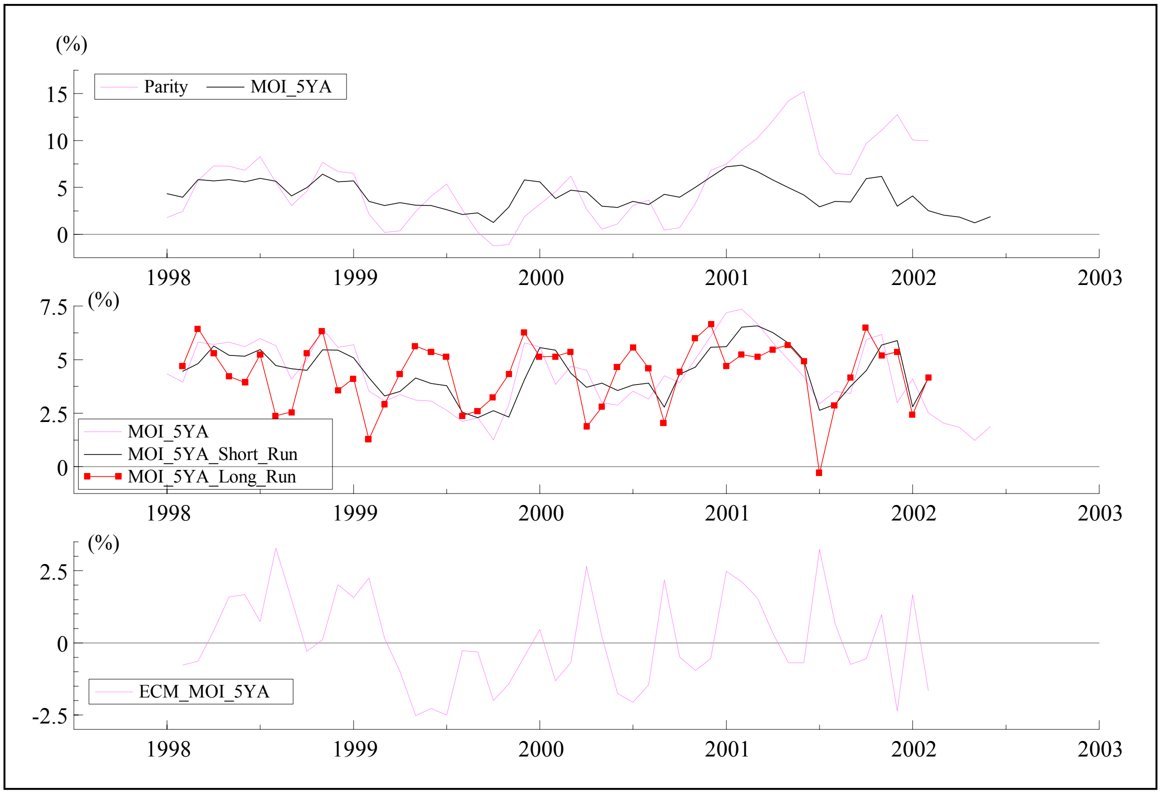
```
Modeling DMOI_5YA by OLS
The present sample is:  1998 (3) to 2002 (2)

Variable       Coefficient    Std.Error  t-value  t-prob PartR^2
Constant          0.017429      0.13733    0.127  0.8996  0.0004
DDParity           0.20830     0.054592    3.816  0.0004  0.2444
ECM_MOI_5YA_1     -0.41280     0.093191   -4.430  0.0001  0.3036

R^2 = 0.363925  F(2,45) = 12.873 [0.0000]  \sigma = 0.948843  DW = 1.85
RSS = 40.51366468 for 3 variables and 48 observations
```

Notes: $DMOI\_5YA = \Delta MOI\_5YA_t$, $DDParity = \Delta\Delta Parity_t$, $ECM\_MOI\_5YA\_1 = ECM(5YA)_{t-1}$.
Source: Own analysis.

Exhibit 6
Deviation of the zloty from its old parity (basket) rate; MOI for 5-year bonds (for period: I 1998 – VI 2002; monthly averages).



Source: Own analysis.

More detailed analysis of ECM (see Table 4) shows significance of an error correction mechanism. The converted parameter (-0,413) suggests that the full correction of discrepancy takes on average about two and a half months.

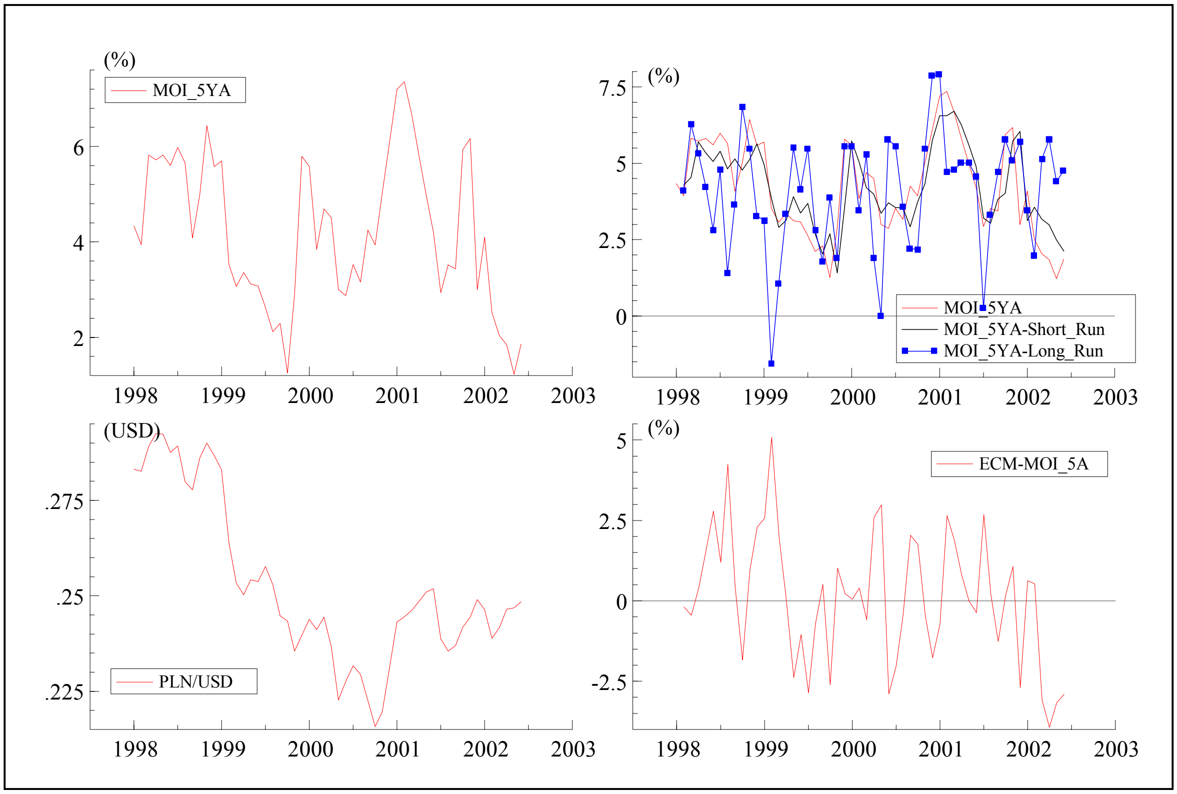
The one period change of MOI(5YA) is explained by 20,8% of change for ΔParity and 41,3% of an error done in the previous period (for the long term function). The model in Table 4 has insignificant constant that is acceptable for this case. Optimism cycles, measured by ECM, are significant factor explaining fluctuations of foreign players participation in the Polish T-bond market. This factor is not directly visible in the bond prices, but its influence is significant. The difference between short-term interest rates and the yields of bonds is cyclically over-priced or under-priced, which results from the zloty rate behavior.

3.3.2 PLN/USD exchange rate

The purpose of the analysis presented in this section was to estimate the influence of the changes in PLN/USD rate on bond yields.

The introductory graphical analysis for daily data suggests the same problems we met in the previous section. Accordingly, we used again the monthly data. The monthly time series are presented at Exhibit 7 (left graphs). Next the comprehensive search for the best model ended with a similar conclusions like it was in section 3.3.1 (compare Table 2 and Table 5). Of course parameters differ, but the specifications are quite the same.

Exhibit 7
Exchange rate of PLN/USD; MOI for 5-year bonds (for period: I 1998 – VI 2002; monthly averages).



Source: Own analysis.

The best model was estimated on 53 monthly observations. The model confirmed that the market optimism index (MOI) is explained not by the size of the divergence of the zloty from its parity rate, but by the change of this divergence. The model presented in this section has better R^2 = 65% than the model obtained in section before[14], but it is more sensitive in modeling short and long term relations. The ECM (see Exhibit 7 – right bottom graph) has bigger and more random oscillations. Also the parameter before (ECM_{t-1}) (see Table 6) is much lower (-0,27). The error is corrected at a slower pace. The full adjustment takes place on average after almost 4 months.

Table 5

MOI as an autoregressive process also dependent on a change for PLN/USD *fx* rate.

```
Modeling MOI_5YA by OLS

The present sample is:  1998 (2) to 2002 (6)
Variable     Coefficient    Std.Error  t-value  t-prob PartR^2
Constant          1.0850      0.38923    2.787  0.0075  0.1345
MOI_5YA_1        0.74677     0.085599    8.724  0.0000  0.6035
DPLN/USD          77.500       21.323    3.635  0.0007  0.2090

R^2 = 0.65049  F(2,50) = 46.529 [0.0000]  \sigma = 0.956571  DW = 1.94
RSS = 45.75144163 for 3 variables and 53 observations


ECM-MOI_5A [1998 (1) to 2002 (6)]
Solved Static Long Run equation

     MOI_5YA =    +4.285                 +306 DPLN/USD
(SE)          (   0.5218)          (    129.8)

ECM = MOI_5YA - 4.28452 - 306.048*DPLN/USD;

WALD test Chi^2(1) = 5.5613 [0.0184] *
```

Notes: MOI_5YA = MOI_5YA_t, MOI_5YA_1 = MOI_5YA_{t-1}, DPLN/USD = $\Delta PLN/USD_t$.

Source: Own analysis.

[14] BTW; the model that do not use ΔPLN/USD but PLN/USD has R^2 about 95%. Then the PLN/USD variable included in the model is for the current period (t) and its first lag (t-1). The parameters before those two variables nearly compensate. Also this model has insignificant long tem modelling and ECM results.

Table 6
Error Correction Model for the model presented in Table 5.

```
Modeling DMOI_5YA by OLS
The present sample is:  1998 (3) to 2002 (6)

Variable      Coefficient    Std.Error  t-value  t-prob PartR^2
Constant        0.0099718      0.13437    0.074  0.9411  0.0001
DDPLN/USD          73.981       19.646    3.766  0.0004  0.2245
ECM-MOI_5A_1     -0.26998     0.072533   -3.722  0.0005  0.2204

R^2 = 0.296668  F(2,49) = 10.334 [0.0002]  \sigma = 0.96374  DW = 1.85
RSS = 45.51096329 for 3 variables and 52 observations
```

Notes: $DMOI\_5YA = \Delta MOI\_5YA_t$, $ECM\text{-}MOI\_5YA\_1 = ECM(5YA)_{t-1}$, $DDPLN/USD = \Delta\Delta PLN/USD_t$.
Source: Own analysis.

Comparing the results from section 3.3.1 and 3.3.2, we find that statistically there are no big differences between the two models. The similarity stems from the fact that the exogenous variables are also similar. Much more interesting there are the differences between models 3.3.1 and 3.3.2. The "parity model" has worse R^2 and better error adjustment in long term modeling. It has some practical consequences and sufficient interpretation. Long term "parity" is a better benchmark variable for expected equilibrium. However, short-term investors do not analyze it for "in" and "out" purposes. Short-term decisions and current market behavior can be better described as a function of PLN/USD.

3.4 Forward interest rates

Empirical results presented in this section show that forward interest rates in the FRA market are influenced by the bond yields. The analysis of current bond yields allows to estimate precisely the behavior of the FRA market.

There are different types of the FRA contracts, which are quoted in the Polish interbank market. For obvious reasons all are strongly correlated (see Table 5). For our modeling purposes we selected only "3x6" FRA contract, which displayed the best correlation with all other contracts (also with those, which are not presented in Table 7). Linear correlation coefficient there is never below 0,99. The path of FRA 3x6 time series is presented together with 2 and 5-year bond yields at Exhibit 8.

Table 7
Correlation matrix for 7 selected FRA rates in Poland[15] (for period VIII 2000 – VII 2001).

Correlation matrix

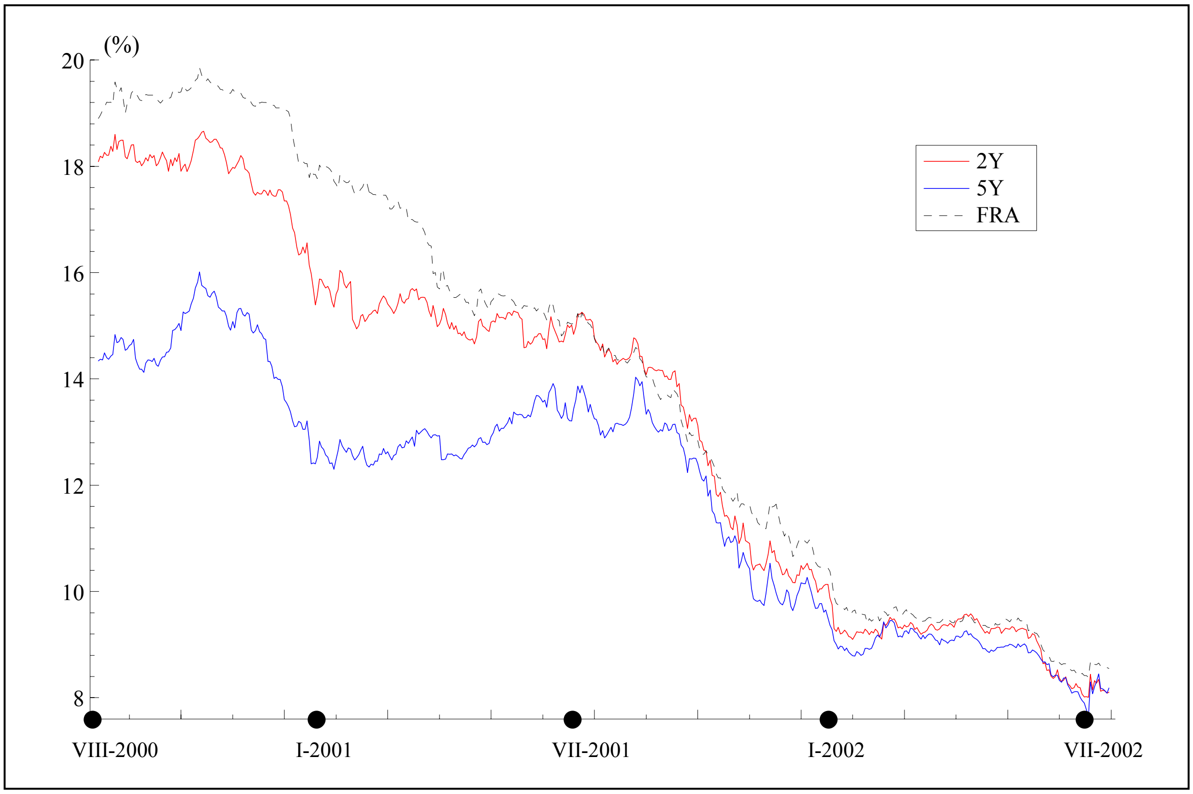
	1x2	1x4	3x6	6x9	1x7	3x9	6x12
1x2	1.0000						
1x4	0.99797	1.0000					
3x6	0.99034	0.99605	1.0000				
6x9	0.97962	0.98873	0.99682	1.0000			
1x7	0.99262	0.99769	0.99920	0.99586	1.0000		
3x9	0.98449	0.99242	0.99844	0.99941	0.99798	1.0000	
6x12	0.97637	0.98617	0.99538	0.99970	0.99419	0.99861	1.0000

Note: E.g. FRA 1x4 = expected 3mths interest rate in 1 mth.
Source: Own analysis.

The search for the best model for forward interest rates covered several detailed analyses for 2 and 5-year bonds. Yield variable was applied on daily basis. There were analysed also its changes, moving averages (for n=21), MOI, etc. Finally the best results obtained are presented in Table 8 and Table 9. FRA occurred to be a strongly autoregressive process AR(1) that additionally is dependent on changes in bond yields. The best two estimated models are presented in formula (5) and (6). They are a typical ADL(p,q) models[16] with insignificant constant.

[15] There were not included FRA: 2x3, 2x5, 9x12, because their quotations started in 2001.
[16] ADL(p,q) model is written as:
$Y_t = a_0 + a_1 Y_{t-1} + a_2 Y_{t-2} + ... + a_p Y_{t-p} + b_0 X_t + b_1 X_{t-1} + b_2 X_{t-2} + ... + b_q X_{t-q} + u_t$.

Exhibit 8
FRA 3x6, yields of 2 and 5-year bonds (for period: VIII 2000 – VII 2002; about 500 daily observations).



Notes: FRA 3x6 = expected 3mths interest rate in 3 mths.
Source: Own analysis.

Table 8
FRA 3x6 and 2-year bond yields (for the period VIII 2000 – VII 2002).

```
Modeling FRA by OLS
The present sample is:  661 to 1149
Variable      Coefficient    Std.Error  t-value  t-prob PartR^2
FRA_1             0.99926   0.00025049   4e+003  0.0000  1.0000
D2Y               0.37290     0.027630   13.496  0.0000  0.2726
D2Y_1             0.10811     0.027588    3.919  0.0001  0.0306
R^2 = 0.999971  \sigma = 0.0791428  DW = 2.12
RSS = 3.044101869 for 3 variables and 489 observations
```

Notes: $FRA = FRA_t$, $FRA\_1 = FRA_{t-1}$, $D2Y = \Delta 2Y_t$, $D2Y\_1 = \Delta 2Y_{t-1}$.
FRA = FRA 3x6 = expected 3mths interest rate in 3 mths.
Source: Own analysis.

Table 9
FRA 3x6 and 2-year bond yields (for the period VIII 2000 – VII 2002).

```
Modelling FRA by OLS
The present sample is:  661 to 1149
Variable     Coefficient    Std.Error  t-value  t-prob PartR^2
FRA_1            0.99900   0.00025410   4e+003  0.0000  1.0000
D5Y              0.34425     0.029244   11.772  0.0000  0.2222
D5Y_1           0.072628     0.029302    2.479  0.0135  0.0125
D5Y_2           0.082441     0.029164    2.827  0.0049  0.0162
R^2 = 0.999969  \sigma = 0.0812784  DW = 1.92
RSS = 3.20399864 for 4 variables and 489 observations
```

Notes: FRA = FRA_t*, FRA_1 =* FRA_{t-1}*, D5Y =* $\Delta 5Y_t$*, D5Y_1 =* $\Delta 5Y_{t-1}$*, D5Y_2 =* $\Delta 5Y_{t-2}$*.*
FRA = FRA 3x6 = expected 3mths interest rate in 3 mths.
Source: Own analysis.

The best-obtained models are:

$$FRA_t = 0,999 * FRA_{t-1} + 0,373 * \Delta 2Y_t + 0,108 * \Delta 2Y_{t-1} + e_t , \quad (5)$$

$$FRA_t = 0,999 * FRA_{t-1} + 0,344 * \Delta 5Y_t + 0,073 * \Delta 5Y_{t-1} + 0,082 * \Delta 5Y_{t-2} + e_t . \quad (6)$$

Empirical results proved that FRA rates are dependent on current and lagged yield change. The opposite relation is statistically less significant. The equation (5) and (6) have very good statistical confidence and good forecasting properties. We can also see that parameters for (Δ2Y) and (Δ5Y) lagged variables do not change sign (the influence is always with "+"). The cumulative effect multiplier for the (Δ2Y) is 0,48 and 0,50 for (Δ5Y). Despite that current FRA rates adjust to yield changes at bond market during 3-4 days. The direct impact and correction are the most important, but the whole correction is distributed in time. 5-year yield changes are a bit more significant but also more distributed in time. The way of obtaining the adjusted equilibrium suggests that the arbitrage between both markets adjust forward interest rates in the FRA market to the implied forward rates in the bond market. A huge R^2 = 99,99% for both models suggest strong connections between those markets.

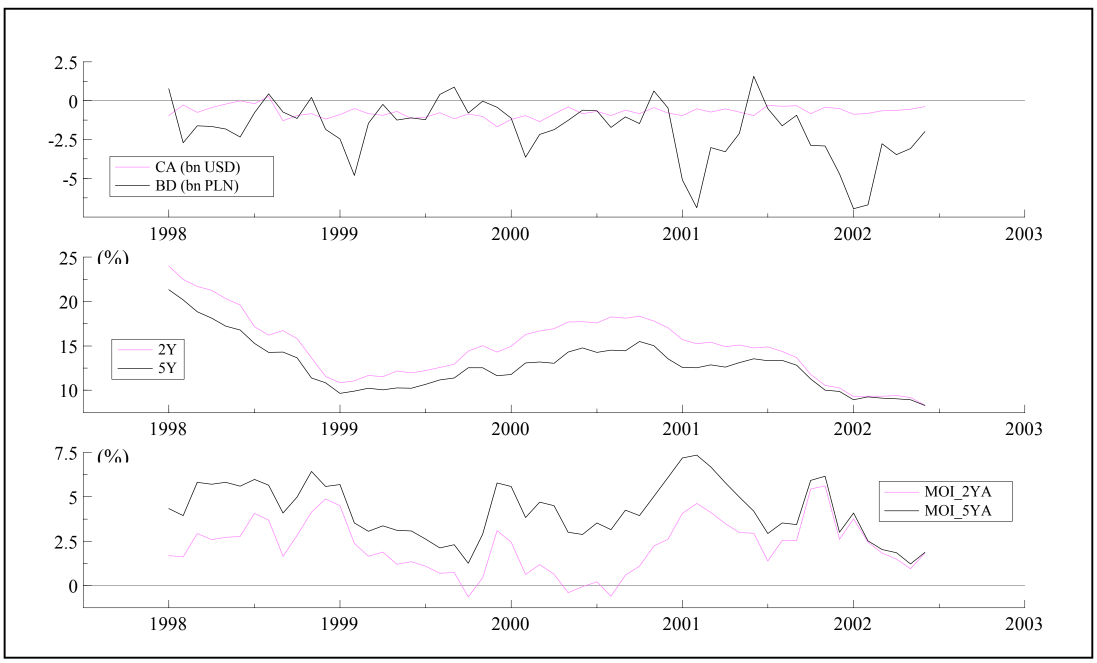
3.5 Budget deficit

Due to the short length of the time series it is difficult to analyze the impact of macroeconomic factors on the Polish bond prices. Nonetheless, these relationships involved are far too important to leave the problem without trying to answer some questions. Especially important is the influence of the budget deficit on the bond prices.

The Ministry of Finance reports budget deficit on monthly basis. Accordingly, it is possible to estimate the real size of budged deficit. Its nominal value can be divided by the index of price level change. Much more difficult is to find the variable, which would be proper proxy for the bond market behavior. Nominal prices or yields are not appropriate, because they depend mainly on other factors. Some opportunities give us the Market Optimism Index, which corresponds to the risk premium. High optimism (high real bond prices) imply low risk premium and vice versa.[17] The change in risk premium can be treated as a control variable for the perception of change in budget deficit.

A brief graphical presentation of nominal budget deficit (BD) shows its seasonality and the constant growth in its volume.

Exhibit 9
Current account deficit (bn USD), budget deficit (bn PLN), MOI (for period: I 1998 – VI 2002; 54 monthly observations). *Source: Own analysis*



The introductory analysis for (BD) and (MOI) suggest that in this pair of variables budget deficit should be treated as an explanatory variable and optimism is a dependent process.

[17] This is true if we assume for modelling purposes that expectations about the changes of future NBP interest rates are fixed for one period time intervals (t,t+1).

Next calculations find out that both processes have a synchronization shift over time. Finally exogenous (BD) is a forward looking variable. The best-obtained model is presented in Table 10 and in formula (7). BD_{t+3} is a forward looking variable. In time (t) it is unknown, but it is predictable. The model confirms that the market is able to estimate it well. The forward looking here is equal 3 months (a quarter). This result is important to see how far the market includes expectations about the future budget deficit into current prices. The estimated model can be utilised as a forecasting tool, but it is rather recommended to apply different models (e.g. obtained in previous sections) for more detailed predictions.

$$MOI\_5YA_t = 0{,}881 * MOI\_5YA_{t-1} - 0{,}223 * BD_{t+3} + e_t \qquad (7)$$

Table 10
Current market optimism (MOI) as a function of expected budget deficit.

```
Modeling MOI_5YA by OLS
The present sample is:  1998 (2) to 2002 (3)
Variable     Coefficient    Std.Error  t-value  t-prob PartR^2
MOI_5YA_1        0.88128     0.041647   21.161  0.0000  0.9032
BD+3            -0.22284     0.072853   -3.059  0.0036  0.1631
R^2 = 0.950838  \sigma = 1.04541  DW = 2.07
RSS = 52.45872543 for 2 variables and 50 observations
```

Notes: MOI_5YA = MOI_5YA_t, *MOI_5YA_1 =* MOI_5YA_{t-1}, *BD+3 =* BD_{t+3}.
Source: Own analysis.

4. Concluding remarks

Our research has confirmed that there is a relationship between the expected interest rates and the bond prices. It confirms also that the changing fundamentals affect bond prices. The empirical results show also that the exchange rate volatility and the fluctuations of market sentiment affect bond pricing. Some of the models presented in the paper seem to be potentially useful in decision making by investors, central bank and fiscal authorities.

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