THE ERROR CORRECTION MODEL OF THE INFLATION BASED ON TWO LONG-RUN EQULIBRIUM RELATIONSHIPS IN BELARUSIAN ECONOMY

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Abstract

The purpose of the given research is the development of the error correction model for consumer price index in Belarus. The basic idea of this model is the use of two long-run equilibrium relationships. The Johansen procedure is applied to test for the number of the long-run relationships. The first long-run relationship is the money demand function; the second one is reflecting manufacturing costs. The evidence suggests that the consumer price index is adjusting to the both relationships. This model is based on the monthly data for the time period from December 1995 to June 2004.

Introduction

Modeling and forecasting of inflation are needed for Central Bank to target the inflation more effectively. Error correction model approach is actively applying for the modeling of inflation. The empirical studies have been conducted both in industrial countries [1, 4] and in countries with transition economy [2, 6, 7].

One of the most commonly used methods of inflation modeling is approach based on the estimation of money demand function. A stable money demand function forms the core in the conduct of monetary policy as it enables a policy-driven change in monetary aggregates to have predictable influences on price.

Charemza and Makarova propose the *LAM*-3 model [2]. The *LAM*-3 model is the latest development in a series of long-run adjustment models, used for simulation and forecasting of several East European economies. Long-run relation for price in their model represents the estimated money demand function.

Johansen and Juselius in [4] investigate the error correction model with the purpose of formulating a control problem as that of making a nonstationary target variable (price level) stationary around a given target value using a given instrument variable (federal fund rate). Based on VECM with four cointegrating relations authors estimate the long-run impact matrix and find that here is significant long-run impact from the federal fund rate to the inflation rate in US economy. But this long-run impact is positive. Thus it is not empirical evidence that the Federal Reserve Bank can reduce the inflation rate in the long run by raising the federal funds rate.

The model of inflation in Belarus based on money demand function is constructed by Pelipas in [7]. The quarter data for 1992-1999 were analyzed. The money demand function adjudicated stable. The further analysis has shown, that in case of infringement of long-term dependence, balance on a money-market is recovered due to money stock and price level.

Kharin, Malugin and Pranovich [6] in propose econometric models system for forecasting and an estimation of variants of a monetary and credit policy in Republic of Belarus. In that system the consumer price index is modelled as disbalance between nominal money stock and demand for real money.

Another approach [1] uses a long-run relationship between inflation and measures of the markup to develop a model for forecasting inflation for the Euro-area using quarterly data over the period June 1973 to March 2002.

An economic substantiation of the model

The estimation of money demand function is based on the Fisher's exchange equation. It is considered that the rise in prices is caused by the excessive monetary supply. Inflation is the single monetary phenomenon in the given concept. In the model the monetary aggregate M1 ($lm1$) is used as the money supply, consumer price index ($lcpi$) is used as the price level, the real gross domestic product smoothed seasonally ($lrgdpsa$) is used as the measure of the transaction relating to the economic activity, the real term deposits interest rate ($ritd$) is used as the assets' return rate which is alternative to M1. Aggregate M1 includes currency plus demand deposits at the commercial banks. Equality between the money supply and money demand function received from Fisher exchange equation is given by [5]:

$$lm1 = b_0 + b_1 lcpi + b_2 lrgdpsa + b_3 ritd \, . \qquad (1)$$

On the other hand the consumer index price depends upon manufacturing cost. As a rule the growth of costs is the consequence of the payment increase without productivity growth and the rise in imported energy carriers prices. Unit labor cost ($lulc$) is used as the measure of the payment increase without productivity growth in the model. Unit labor cost is calculated as the compensation to employees divided by the nominal gross domestic product. The price for oil ($loilpir$) is recognized as the most adequate for the illustration of the imported energy carriers prices. Thus the described relationship is given by the equation:

$$lcpi = b_0 + b_1 lulc + b_2 loilipr . \quad (2)$$

Vector error correction model

Let Y_t be a $(n \times 1)$ vector of economic time series. It is possible to specify the model Y_t as an unrestricted vector autoregression (VAR) involving up to k -lags of Y_t:

$$Y_t = \Pi_1 Y_{t-1} + ... + \Pi_k Y_{t-k} + \Phi D_t + \varepsilon_t, \, t = 1, ..., T, \quad (3)$$

where Π_i, Φ are $(n \times n)$ matrix's of parameters, ε_t is assumed to be independent and Gaussian distributed with mean zero and variance Ω. The variable D_t contains deterministic terms such as a constant, a linear trend and seasonal dummies.

Equation (3) can be reformulated into a Vector error correction (VECM) from:

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta Y_{t-i} + \Phi D_t + \varepsilon_t, \, t = 1, ..., T, \quad (4)$$

where $\Pi = \sum_{i=1}^{k} \Pi_i - I, \Gamma_i = -\sum_{j=i+1}^{k} \Pi_j$. It is well known that if the characteristic polynomial, here given by $A(z) = (1-z)I - \Pi z - \sum_{i=1}^{k-1} \Gamma_i (1-z) z^i$, has all its roots outside the unit-disk, then Y_t is stationary. If the polynomial has one or more unit roots, then Y_t is an integrated process as defined by Johansen [3]. A unit root implies that Π has reduced rank $r < n$ and if the number of unit roots equals $n - r$; then the process Y_t is integrated of order one, denoted I(1). When Π has reduced rank, it can be written as a product of two $(n \times r)$ matrices $\Pi = \alpha \beta'$, such that the model can be expressed in the form:

$$\Delta Y_t = \alpha \beta' Y_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta Y_{t-i} + \Phi D_t + \varepsilon_t, \, t = 1, ..., T, \quad (5)$$

This process can be inverted to an infinite moving average representation, also known as the

Granger representation [3]. So β is the matrix of the long-run coefficient, $\beta' Y_{t-1} = 0$ is the long-run equilibrium relationships, r is the number of long-run relationships and α represents the speed of the adjustment to the equilibrium.

Estimation

Vector Y_t used in model consists of the following monthly variables:

$$Y'_t = \{ lm1_t, lcpi_t, lrgdpsa_t, ritd_t, lulc_t, loilipr_t), \quad (6)$$

where $t = 1995:12 - 2004:6$ and all variables are in natural logarithm except for interest rate $ritd$. Prior analysis has displayed that the series don't contain the structural break and the seasonal adjustments. Analyses with DF and ADF tests showed that all series may be regarded as the integrated time series of order 1.

The rank of the β matrix being the equivalent to the number of the long-run equilibrium relationships is tested by the Johansen procedure [3] in the following assumptions: there is an intercept in the lung-run equation and VECM; differenced endogenous lag is included in the model $(k = 2)$. The trace statistic and the maximum eigenvalue statistic suggests that there are two long-run equilibrium relationships of the variables (see Table 1).

Table 1

Test of the number of the long-run equilibrium relationships

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5 Percent Critical Value	1 Percent Critical Value
None	**0.582595**	**177.2962**	**94.15**	**103.18**
At most 1	**0.392871**	**89.92645**	**68.52**	**76.07**
At most 2	0.218860	40.02510	47.21	54.46
At most 3	0.102948	15.32507	29.68	35.65
At most 4	0.032609	4.460888	15.41	20.04
At most 5	0.011391	1.145673	3.76	6.65
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	5 Percent Critical Value	1 Percent Critical Value
None	**0.582595**	**87.36974**	**39.37**	**45.10**
At most 1	**0.392871**	**49.90134**	**33.46**	**38.77**
At most 2	0.218860	24.70003	27.07	32.24
At most 3	0.102948	10.86418	20.97	25.52
At most 4	0.032609	3.315216	14.07	18.63
At most 5	0.011391	1.145673	3.76	6.65

Further testing structural restriction on matrix of long-run coefficient has been made. Tested restriction can be written as:

$$\beta' = \begin{pmatrix} -1 & * & * & * & 0 & 0 \\ 0 & 1 & 0 & 0 & * & * \end{pmatrix}, \tag{7}$$

where * means that the corresponding coefficient is estimated without restriction. The restriction was tested with likelihood ratio test procedure [3] and accepted with a p-value of 0.84. The first long-run relationship represents a money demand and is given by (with t-statistics under estimated coefficients):

$$\underset{}{lm1_t} = \underset{(45.00)}{0.805 lcpi_{t-1}} + \underset{(15.52)}{3.09 lrgdpsa_{t-1}} - \underset{(3.00)}{0.166 ritd_{t-1}} - 0.182 + ecm1_t. \tag{8}$$

The interpretation is that the money demand function has a stable form. Also the consumer price index and the real gross domestic product relatively increase to the money demand when the real interest rate is negative.

The second long-run relationship representing a manufacturing cost is given by:

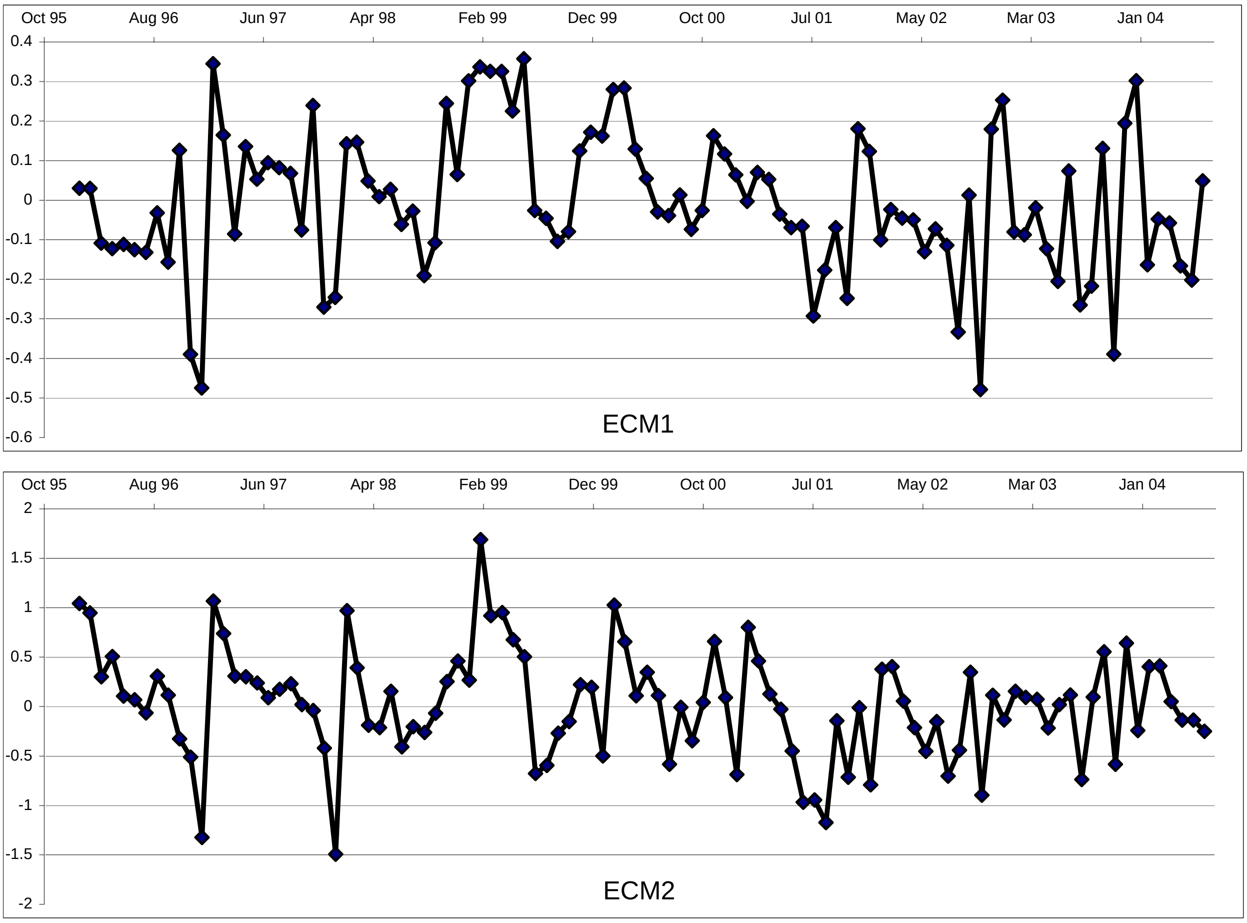
$$lcpi_t = \underset{(13.89)}{4.448 lulc_t} + \underset{(21.00)}{0.633 loilipr_t} + 0.734 + ecm2_t. \tag{9}$$

The interpretation is that the customer price index is positively related both to the unit labor cost and to the price for oil. Figure 1 shows deviations from the first long run equilibrium relationship ($ecm1$) and the second one ($ecm2$).

At inclusion in the second long-run relationship of the real interest rate the factor appeared statistically insignificant. It speaks about absence of influence of the price for the capital on cost of manufacturing. The capital market in Belarus is insufficiently developed.

Figure *1*

Deviations from the long run equilibrium relationships



Using the identified cointegration relations have been estimated a VECM. By removing insignificant lagged variables from the system, based t-test, we arrived at the model presented in Table 2 (with t-statistics in brackets). The table heading column indicates the dependent variables in each of the model equations, while the row headings indicate the conditioning variables. In Table 2 ler is the market exchange rate of Belarusian ruble to US dollar, D9809 and D9811 are the dummy variables. In result it is possible to specify the following kind of dependence for the first difference of the consumer price index:

$$\begin{aligned}\Delta lcpi_t \; = \; & -0.019 ecm1_{t-1} - 0.008 ecm2_{t-1} - 0.006 + 0.729\,\Delta lcpi_{t-1} + \\ & + 0.091(\Delta lm1_{t-6} + \Delta lm1_{t-7}) + 0.123\,\Delta ler_t + 0.088 D9809 + 0.052 D9811.\end{aligned} \tag{10}$$

The custom price index is adjusting to $ecm1$ (the money demand function) and to $ecm2$ (the manufacturing cost relation). The adjustment coefficients are negative, it corresponds to the economic interpretation.

Table 2

Estimated Vector error correction model

Error Correction:	$\Delta lm1_t$	$\Delta lcpi_t$	$\Delta lrgdpsa_t$	$\Delta ritd_t$	$\Delta lulc_t$	$\Delta loilipr_t$
$ecm1_{t-1}$	0.063602	**-0.018656**	-0.358413	0.236797	0.061862	-0.042796
	[2.12280]	**[-2.01861]**	[-8.46551]	[2.12718]	[0.66996]	[-0.40556]
$ecm2_{t-1}$	-0.018393	**-0.007576**	0.024775	0.096818	0.191250	0.038109
	[-1.94963]	**[-2.60340]**	[1.85840]	[2.76215]	[6.57790]	[1.14693]
Intercept	0.052621	**-0.005630**	-0.034841	0.031267	0.069631	0.017924
	[6.39690]	**[-2.21864]**	[-2.99725]	[1.02303]	[2.74657]	[0.61865]
$\Delta lcpi_{t-1}$	0.167065	**0.729176**	0.670283	3.301251	-0.946756	0.043532
	[1.21765]	**[17.2286]**	[3.45718]	[6.47593]	[-2.23901]	[0.09009]
$\Delta lm1_{t-6} + \Delta lm1_{t-7}$	-0.098366	**0.090523**	0.118429	-0.838071	-0.103760	-0.155059
	[-1.36376]	**[4.06847]**	[1.16193]	[-3.12723]	[-0.46677]	[-0.61038]
Δler_t	0.122168	**0.123426**	-0.029804	-1.459159	-0.203234	1.143506
	[1.79193]	**[5.86886]**	[-0.30936]	[-5.76042]	[-0.96726]	[4.76226]
$D9809$	-0.014589	**0.088191**	-0.118756	-0.957861	0.053640	-0.096766
	[-0.34946]	**[6.84833]**	[-2.01308]	[-6.17540]	[0.41691]	[-0.65812]
$D9811$	0.010981	**0.052221**	-0.123818	-0.584948	0.113536	-0.237568
	[0.27960]	**[4.31036]**	[-2.23097]	[-4.00855]	[0.93799]	[-1.71744]
R-squared	0.188418	**0.944242**	0.534767	0.764583	0.492554	0.323182
Adj. R-squared	0.102486	**0.938338**	0.485507	0.739656	0.438824	0.251518
Sum sq. resids	0.114174	**0.010864**	0.227989	1.576143	1.084442	1.416277
S.E. equation	0.036650	**0.011306**	0.051790	0.136172	0.112952	0.129082
Log likelihood	184.5863	**296.3175**	151.7367	59.89840	77.65939	64.97850

Results of the autocorrelation LM test (with minimal a p-value of 0.17) and autocorrelation Portmanteau test (with minimal a p-value of 0.39) reveal that there is no residuals' autocorrelation. The join Jarque-Bera statistic testifies that it's impossible to reject the null hypothesis of the normal distribution residuals with a p-value of 0.39. White's test statistics is 247.31 and it's impossible to reject the null hypothesis of no heteroskedasticity with a p-value of 0.57.

Now we consider the estimated impulse response function, which will allow to mapping the response of the consumer price index to innovations in the other variables. Figure 2 indicates that shock of the prices causes continuation of an inflationary tendency the next months, thus his force fades by degrees during eight months.

Figure 2

Response of LCPI to LCPI

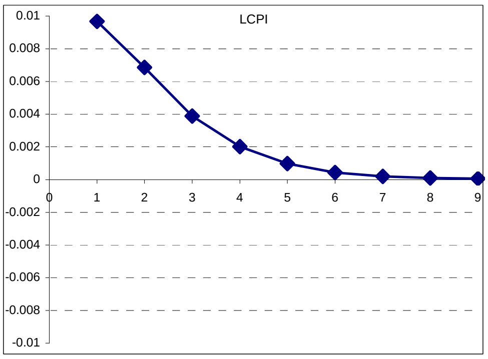


Figure 3

Response of LCPI to LM1

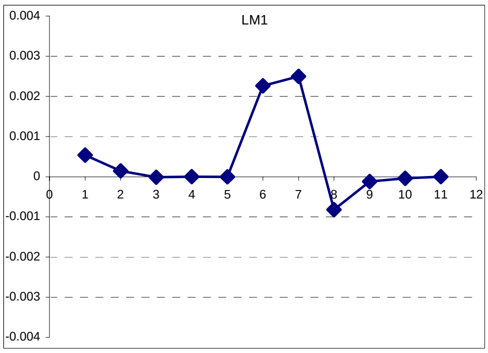


Figure 4

Response of LCPI to LULC

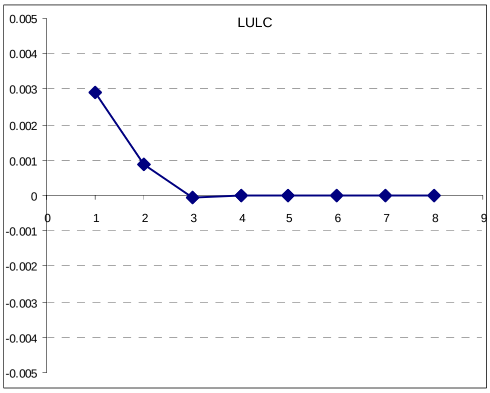


Figure 5

Response of LCPI to LOILPIR

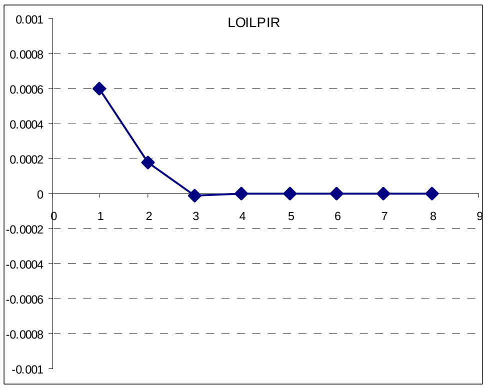


Figure 6

Response of LCPI to LRGDPSA

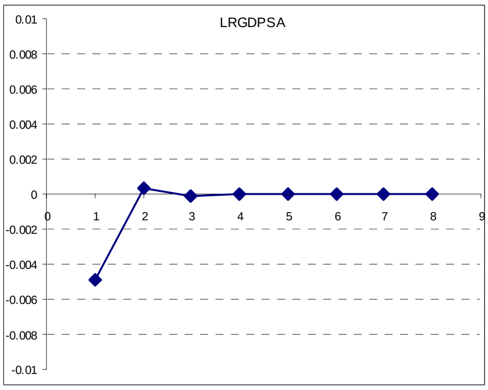
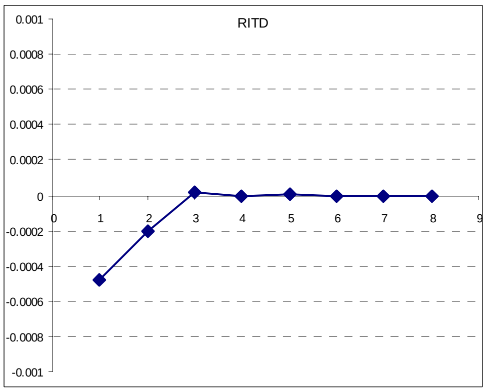


Figure 7

Response of LCPI to RITD



The Figure 3 shows that the increase in money supply causes less significant increase of a consumer price index in first four months and more a considerable increase during the sixth and seventh month. Apparently from Figures 4 and 5, jump in Unit labor cost and the price for oil causes inflation process which fades during three months.

Based on the result in Figures 6 and 7, it appears that the increase in real gross domestic product, as well as in the real term deposits interest rate leads to reduction of the prices during two months.

For research forecasting properties of the model were constructed dynamic forecasts of the consumer price index and its monthly growth. Results are submitted on the Figure 8,9.

Figure 8

The actual value and forecast of Consumer price index

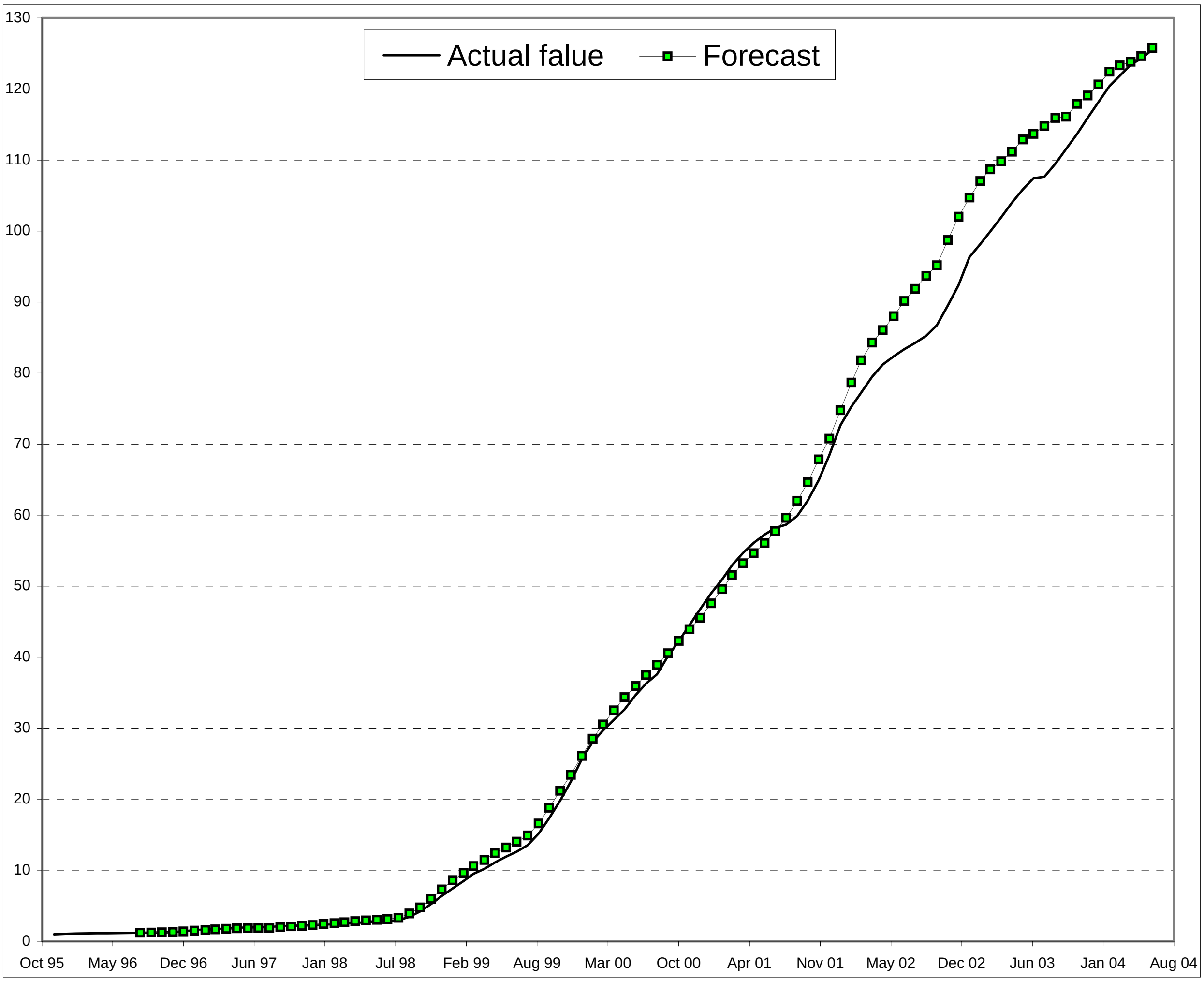
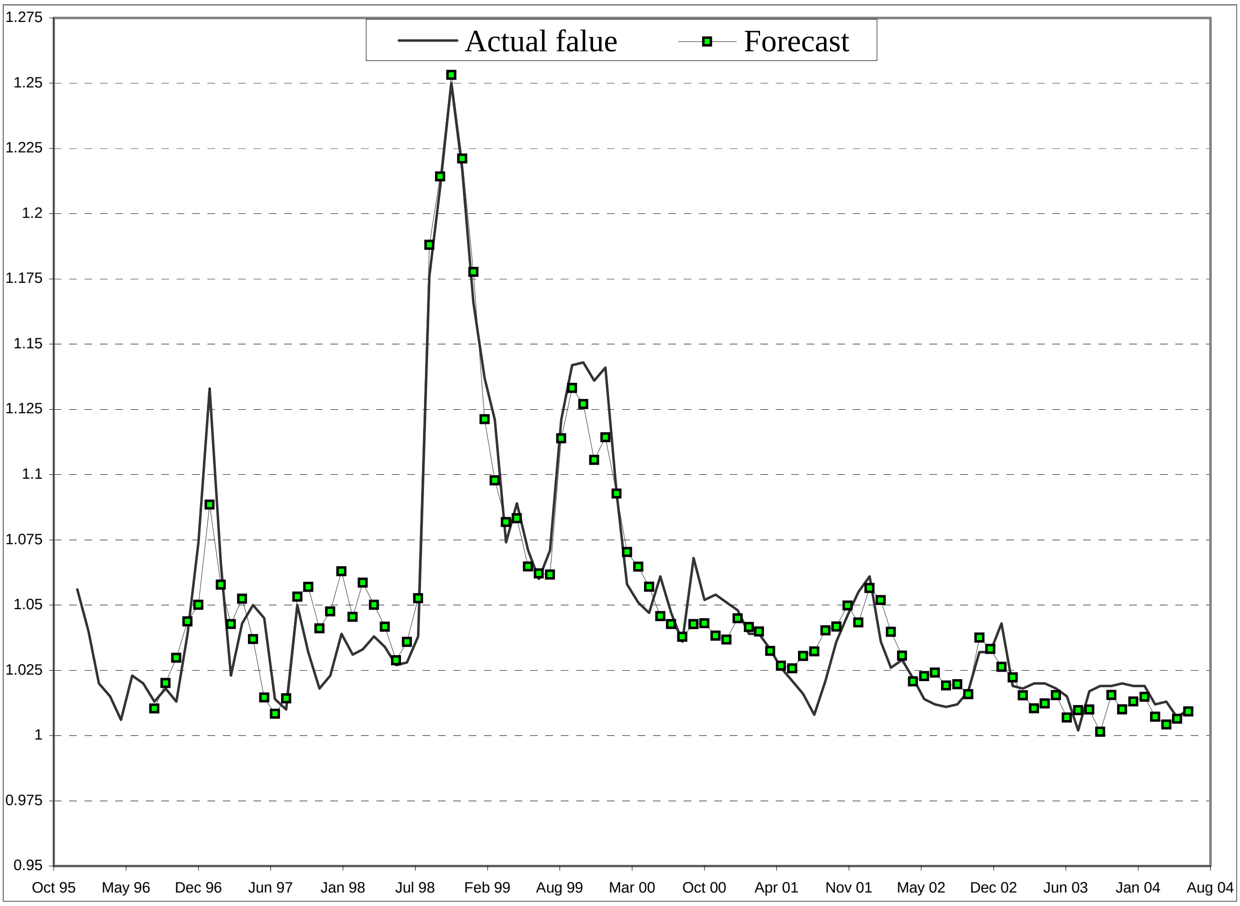


Figure 9

The actual value and forecast of monthly growth of Consumer price index



Conclusion

In the constructed model all factors are statistically significant. Signs of coefficient correspond to economic interpretation. The analysis of the residuals and variance specifies adequacy of the model. It is important that the consumer price index is corrected to both long-run equilibrium relationships. The model can be used for forecasting and the analysis of inflationary process. Distant research with the purpose of improvement of the model can be connected to the modeling of structural break in the Vector error correction model.

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