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ON THE RELATIONSHIP BETWEEN INFLATION AND INFLATION UNCERTAINTY: EXAMINING SOME BALKAN COUNTRIES

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Abstract: The purpose of this paper is to find out econometrically what characterizes the inflation-uncertainty relationship in the Balkan region. Three economies (Serbian, Bulgarian and Romanian) are considered for period 2001-2008. Given the previous history of high and even hyperinflation in the Balkan region, this econometric analysis may enable better understanding of the dynamic structure of inflation, its uncertainty and of their co-movements. Furthermore, the effectiveness of fiscal and monetary policy undertaken may be assessed based on the results of empirical work. Using monthly data several GARCH specifications are estimated providing measure for inflation uncertainty. Derived variables are then included in VAR model to test for Granger-causality between inflation and its uncertainty. Permanent and transitory components of inflation rate are also extracted to examine inflation-uncertainty relationship at long and short horizon. Main conclusion of the paper is that high inflation invokes high uncertainty in all economies considered, while causality in reverse direction was found only for the long-run price component in Serbia.

Keywords: *GARCH model, inflation rate, the Cukierman-Meltzer hypothesis, the Friedman-Ball hypothesis, VAR model.*

1. INTRODUCTION

The cost of inflation has been a subject of substantial interest in macroeconomy. Given that inflation uncertainty represents one of the major sources of this cost, the relationship between inflation and its uncertainty has attracted considerable attention of both applied and theoretical macroeconomists. The issue was first brought up by Friedman [19], who, in his well-known Nobel Prize speech, argued that increased inflation has a potential to create nominal uncertainty that subsequently lowers welfare and possible output growth. The Friedman idea was later formalized by Ball [4]. The relationship between inflation and inflation uncertainty was also considered in reverse direction, such that high inflation uncertainty may induce higher average inflation, as advocated by Cukierman and Meltzer [11], [12].

The relationship between inflation and inflation uncertainty has been investigated in a number of empirical papers. The G7 advanced economies were most frequently analyzed. Recently some emerging market economies have also been considered. The empirical results reached do not uniformly support either the Friedman-Ball or the Cukierman-Meltzer point of view.

The purpose of this paper is to econometrically find out what characterizes the inflation-uncertainty relationship in three Balkan countries during 2001-2008 period: Serbia, Romania and Bulgaria. Given the previous history of high and even hyperinflation in this region, and that transition process has changed the pattern of inflation rate evolution, this econometric analysis may enable further insight into the dynamic structure of inflation, its uncertainty and the co-movements of two. Most attention will be paid to Serbian economy that has entered transition process relatively late in comparison with the neighboring countries. Permanent and transitory components of Serbian inflation rate will be extracted to examine inflation-uncertainty relationship at long and short horizons. Finally, the inflation-uncertainty relationship will be considered for Romanian and Bulgarian economies that succeeded in keeping inflation rate at relatively low level in recent years. However, the issue of impact inflation uncertainty has on overall economic performances is still important.

The structure of the paper is as follows. Section 2 shortly reviews theoretical background of inflation-uncertainty relationship, and existing empirical results. Section 3 discusses main methodological issues. Section 4 provides empirical results obtained for Serbian economy. Modelling of Romanian and Bulgarian inflation rates are reported in Section 5. Section 6 concludes.

2. THEORETHICAL BACKGROUND OF RELATIONSHIP BETWEEN INFLATION AND INFLATION UNCERTAINTY

Relationship between inflation and inflation uncertainty consists of a two-way causality. The one-way causality running from inflation to its uncertainty is known as the Friedman-Ball hypothesis, while the causality running in opposite direction, from inflation uncertainty to inflation, is taken as the Cukierman-Meltzer hypothesis.

As already emphasized, Friedman [19] was the first to point out that changes in inflation may induce erratic responses of monetary authorities, which may lead to more uncertainty about the future inflation. This conjecture was formally justified by Ball [4] who used the asymmetric information game model in which the public faces two types of policy-makers that differ in terms of their willingness to bear the economic costs of reducing inflation. Policy-makers stochastically alternate in office. Therefore, an increase in inflation raises uncertainty about the path of the future inflation, because it is not known how long it will be before the tough type gain power and takes measures against high inflation.

Causality that runs from inflation uncertainty to inflation was first discussed by Cukierman and Meltzer [12]. This result is derived from a game-theoretic model of FED behavior under the assumption that FED dislikes inflation, but is willing to stimulate the economy growth by creating inflation surpluses. Both the policy-maker’s objective function and the money supply process are assumed to be random variables. Although the expectations are rational, information is imperfect due to imprecise monetary control mechanism. As a result, the public cannot make correct inference on future inflation. Consequently, increase in inflation uncertainty raises the optimal average inflation rate by making the incentive for the policy-makers to produce inflation surplus. Hence, inflation uncertainty has a positive impact on inflation. By contrast, Holland [21] suggested that this link could be negative, such that high inflation uncertainty reduces level of inflation rate, due to the stabilization motive of the monetary authorities.

The analysis of inflation-uncertainty relationship is extended when decomposition of inflation into its permanent and transitory components is taken into account. As noted by Ball and Cecchetti [5], inflation may react differently to inflation uncertainty in the long-run and in the short-run. Vice versa, uncertainty may not be affected in the same way by the permanent and the transitory shocks of inflation. This decomposition may be relevant to evaluate the efficiency of monetary and fiscal policies, because the behavior of inflation in the long-run is usually associated with the monetary policy, while the short-run variations are often due to changes in fiscal policy.

Both the Friedman-Ball and the Cukierman-Meltzer hypotheses were frequently tested in numerous empirical analyses. Among papers we were able to find there are more in favor of the Friedman-Ball view [1], [8],[9], [13], [18], [20], [28], [29] than those that do not support it [7], [10], [16], [22]. The validity of the Cukierman-Meltzer hypothesis has not been investigated as often, but most of the existing results either support this view [1], [2], [9], [13] or give mixed conclusions [29].

3. MAIN METHODOLOGICAL ISSUES

There are three key methodological issues in the econometric modelling of inflation-uncertainty relationship. The first one deals with the measure of inflation uncertainty. The second issue provides framework for making inference on direction of causality between inflation and uncertainty. The third issue considers approach followed to obtain permanent-transitory decomposition of inflation.

Some standard measure of inflation variability is often used to approximate its uncertainty. However, there could be a significant difference between variability and uncertainty of inflation depending on whether the variability is predictable in the model under consideration [20]. Therefore, the class of generalized autoregressive conditional heteroskedasticity models (GARCH models) emerges as a natural framework for this analysis for at least two reasons [7], [20], [30]. First, GARCH models explicitly specify and estimate variance of the unpredictable innovation in inflation. Second, based on GARCH models a time-varying conditional residual variance may be derived that is in accordance with the notion of uncertainty discussed in theoretical papers [20].

We will shortly overview GARCH models used in our empirical work. The simple GARCH(1,1) model reads as follows [7], [15], [30]:

$$\pi_t = \beta_0 + \sum_{i=1}^{p} \phi_i \pi_{t-i} + \sum_{j=1}^{q} \theta_i \varepsilon_{t-j} + \sum_{j=1}^{m} \delta_j D_j + \varepsilon_t, \varepsilon_t = \sigma_t u_t, u_t : \text{iid } N(0,1) \tag{3.1}$$
$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \sigma_{t-1}^2, \alpha_0 > 0, \alpha_1 \geq 0, \alpha_2 \geq 0, \alpha_1 + \alpha_2 < 1.$$

Mean equation for inflation, π_t, is expressed in the form of ARMA(p,q) model in which dummy variables D_j, j=1,…,m, may be included to capture the effects of outliers. Volatility equation describes conditional variance, σ_t^2, of an error term ε_t, as a function of its own lagged-one value and the lagged-one value of the squared error term ε_t. Parameters of the model are: $\beta_0, \phi_1, ..., \phi_p, \theta_1, ..., \theta q, \delta_1, ..., \delta_m, \alpha_0, \alpha_1, \alpha_2$.

Among different modifications of GARCH models suggested in the literature the power GARCH model (PGARCH model) was also applied in our empirical analysis. The PGARCH (1,1) specification gives the volatility equation of the form:

$$\sigma_t^{\eta} = \alpha_0 + \alpha_1 |\varepsilon_{t-1}|^{\eta} + \alpha_2 \sigma_{t-1}^{\eta}, \alpha_0 > 0, \alpha_1 \geq 0, \alpha_2 \geq 0, \alpha_1 + \alpha_2 < 1, \eta > 0. \tag{3.2}$$

PGARCH model allows for explicit estimation of power η. Under the restriction η=1, the conditional standard deviation is modeled within the volatility equation. This is the case of restricted PGARCH model.

Parameters of GARCH and restricted PGARCH models are estimated by the method of maximum likelihood. In practice, the maximum of the likelihood function is found by the standard numerical optimization methods, among which the BHHH algorithm is the most commonly implemented [17], [30]. Estimated conditional variance ($\hat{\sigma}_t^2$) is taken as a measure of uncertainty [20].

In order to assess a direction of causality between inflation and its uncertainty the use of vector autoregressive model (VAR model) has been advocated in the literature. This is one of the most popular specifications in macroeconometric analysis, since it completely captures dynamic structure among variables of interest. VAR model of order *k* between inflation and inflation uncertainty derived from GARCH specifications is postulated in the following way:

$$\begin{aligned} \pi_t &= a_{10} + \sum_{i=1}^{k} a_{1i}\pi_{t-i} + \sum_{j=1}^{k} b_{1j}\hat{\sigma}^2_{t-j} + e_{1t} \\ \hat{\sigma}^2_t &= a_{20} + \sum_{i=1}^{k} a_{2i}\pi_{t-i} + \sum_{j=1}^{k} b_{2j}\hat{\sigma}^2_{t-j} + e_{2t}, \end{aligned} \tag{3.3}$$

and e_{1t} and e_{2t} are Gaussian white noise processes uncorrelated at lags different from zero.

The Friedman-Ball hypothesis of causality running from inflation to uncertainty cannot be rejected if inflation Granger-causes uncertainty. This causality implies that the null hypothesis, $H_0 : a_{21} = a_{22} = ... = a_{2k} = 0$, tested against the alternative that the null is not true, cannot be accepted.

The Cukierman-Meltzer hypothesis of causality stemming from inflation uncertainty to inflation can be accepted if the null hypothesis, $H_0 : b_{11} = b_{12} = ... = b_{1k} = 0$, tested against the alternative that this null hypothesis is not valid, can be refuted. This means that uncertainty Granger-causes inflation. If this is the case, then the sign of the sum $\sum_{j=1}^{k} b_{1j}$ shows whether inflation uncertainty leads to increase or decrease in the level of inflation rate.

Decomposition of time series into its permanent and transitory components can be done in different ways. In this paper we follow signal extraction approach of unobserved components hidden in an observed time series for which ARIMA model can be identified. [24]. Components are estimated by Wiener-Kolmogorov filter applied to non-stationary series [3]. Permanent component, being approximated by trend-cycle component, accounts for the stochastic trend and thus explains the behavior in the long-run. Transitory component is stationary and contains irregular variations.

4. MODELLING INFLATION RATE IN SERBIA[1]

Monthly consumer price index (CPI index, 2001=100) in Serbia is considered for period: January, 2002 – March, 2008 (75 observations). Data are obtained from the following internet addresses: www.nbs.yu and www.statserb.sr.gov.yu. Inflation rate is calculated as the first difference of the logarithm of CPI ($\pi_t = log\, CPI_t - log\, CPI_{t-1} = \Delta log\, CPI_t$). Consumer price index has a strong upward trend which is described by the unit-root presence, while inflation rate appears to be stationary, but with the several outliers due to changes in economic policy (Graph 4.1).

One of the key features of time series in transition economies is the presence of structural breaks. They should be taken into account, because if they are neglected, then misleading statistical and invalid economic conclusions may be drawn [25]. Outliers in the level of inflation rate in Serbia occurred due to the following events: administrative change of the price of electricity in July, 2002; administrative change of communal utility prices in December 2004; introduction of VAT in January, 2005 and change in monetary policy due to start of inflation targeting in September, 2006. The effects of these interventions are eliminated from inflation rate by including appropriate impulse dummy variables that take only non-zero value one for the month the change was detected. Such time series, which is corrected for outliers, is a subject of econometric analysis in this paper.

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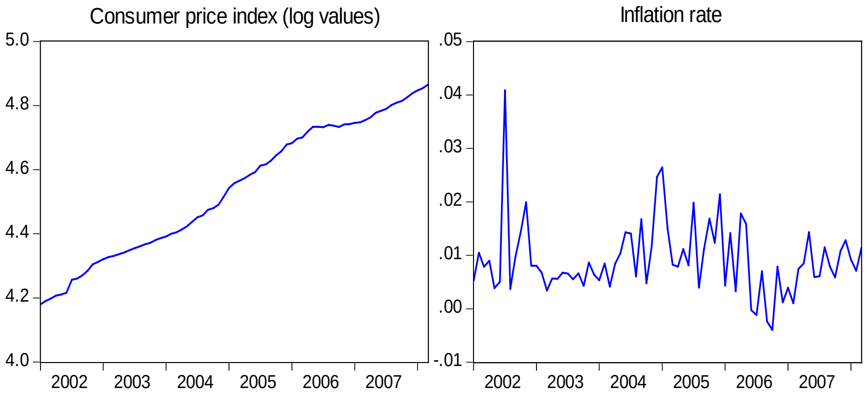
[1] All empirical results in the paper are obtained using software EVIEWS 6.0 [17] and WINRATS 6.20 [27].

Graph 4.1 Consumer price index and inflation rate



Ordinary (AC) and partial autocorrelation (PAC) functions are estimated in order to discover dynamic structure in the mean and variability of inflation rate. Values reported in Table 4.1 suggest that mean equation should probably contain autoregressive components up to order two. Also, variability appears to be unstable, which justifies the application of GARCH specification.

Table 4.1 Correlation structure of the inflation mean and variance

Lag	1	2	3	4	5	6
Inflation rate						
AC	0.16	0.32	0.17	0.17	0.15	-0.10
PAC	0.16	0.30	0.10	0.05	0.06	-0.23
Squared inflation rate						
AC	0.04	0.14	0.23	0.12	0.24	0.08
PAC	0.04	0.14	0.23	0.10	0.19	0.02

Note: The 95% confidence interval is [-0.23; 0.23].

Following PGARCH(1,1) models gives the most satisfactory results:

Model I:

$$\begin{aligned}
&\hat{\pi}_t = \underset{(0.0001)}{0.008} + \underset{(0.130)}{0.261}\pi_{t-1} + \underset{(0.126)}{0.302}\pi_{t-2}\\
&\hat{\sigma}_t = \underset{(0.4e^{-3})}{0.65e^{-3}} + \underset{(0.130)}{0.245}|\varepsilon_{t-1}| + \underset{(0.192)}{0.658}\sigma_{t-1}\\
&JB = 4.09(0.13), ARCH(4) = 2.57(0.63),\\
&Q(12) = 13.72(0.10),\ Q^2(12) = 12.22(0.27),\ L = 287.3461.
\end{aligned} \tag{4.1}$$

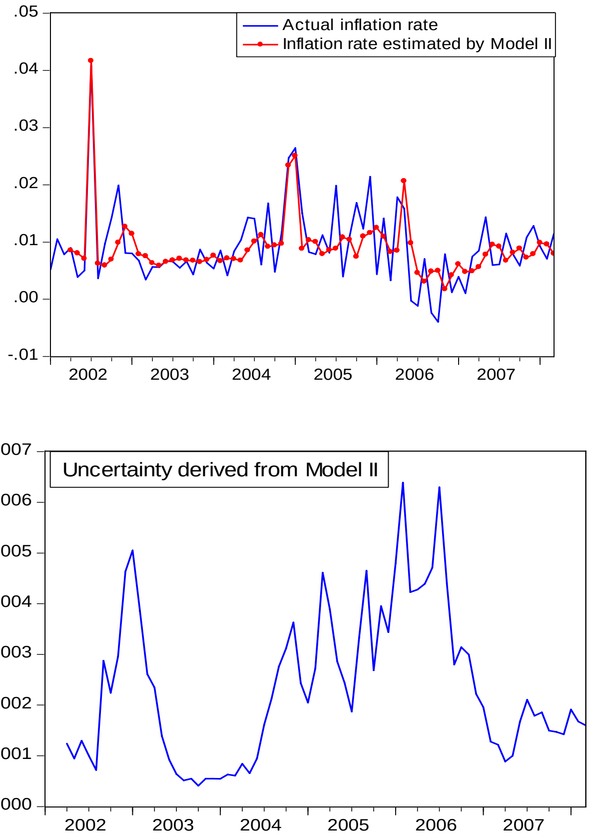
Model II:

$$\begin{aligned}
&\hat{\pi}_t = \underset{(0.001)}{0.008} + \underset{(0.126)}{0.248}\pi_{t-1} + \underset{(0.117)}{0.300}\pi_{t-2}\\
&\hat{\sigma}_t = \underset{(0.4e^{-3})}{-0.5e^{-4}} + \underset{(0.097)}{0.199}|\varepsilon_{t-1}| + \underset{(0.137)}{0.700}\sigma_{t-1} + \underset{(0.029)}{0.074}\pi_{t-2}\\
&JB = 3.62(0.16), ARCH(4) = 4.11(0.39),\\
&Q(12) = 13.33(0.21),\ Q^2(12) = 10.54(0.39),\ \ L = 289.7560.
\end{aligned} \tag{4.2}$$

Note: The BHHH algorithm is used in estimation. The Bollerslev-Wooldrige standard errors are calculated and given in (.) below the coefficient estimates. The mean equation contains dummy variables previously introduced. The following test-statistics are reported: JB is the Jarque-Bera test-statistic for normality of residuals that under the null of normality has $\chi^2(2)$ distribution; ARCH(4) is the Lagrange multiplier test statistic for testing the fourth-order autocorrelated squared residuals that under the null of no autoregressive heteroskedasticity has $\chi^2(4)$ distribution; Q(12) is the Box-Ljung test-statistic for the residual autocorrelation of order 12 that under the null of no serial correlation has a $\chi^2(9)$ distribution and $Q^2(12)$ is the Box-Ljung test-statistic for autocorrelated squared residuals that under the null of no autoregressive heteroskedasticity also has a $\chi^2(9)$ distribution. Residuals are standardized. The *p*-values are reported in (.) after a statistic. *L* denotes the final log-likelihood function value.

In Graph 4.2 mean inflation and uncertainty derived from model II are depicted. Mean inflation is approximated well by this model. Estimated volatility exhibits instability over time, and its surge seems to coincide with the increase in the level of inflation rate.

Graph 4.2 Estimated mean inflation and volatility from Model II



To determine in which way the causality between inflation and its uncertainty runs the VAR models of inflation and inflation uncertainty, derived from estimated GARCH specifications, are postulated and estimated. The results of the Granger-causality tests are reported in Table 4.2. These results uniformly suggest one-way causality stemming from inflation to uncertainty. Hence, the Friedman-Ball hypothesis can be accepted as valid, while the Cukierman-Meltzer hypothesis cannot. This finding is supported by the specification (4.2) in which inflation lagged-two period appears as significant explanatory variable in volatility equation.

Table 4.2 Granger-causality test between inflation and its uncertainty

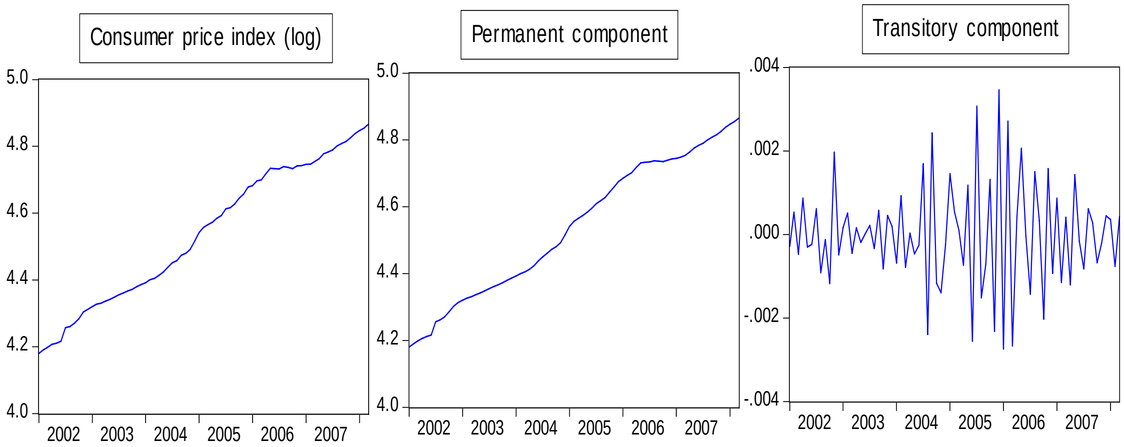
VAR model between inflation and uncertainty		Ho: Inflation does not Granger-cause uncertainty	Ho: Uncertainty does not Granger-cause inflation
Model I	k=1	3.87(0.05)	1.28(0.26)
	k=2	4.61 (0.10)	2.83 (0.34)
Model II	k=2	67.54(0.00)	1.58(0.45)
	k=4	64.55(0.00)	7.16(0.13)

Note: The number of lags (k) in VAR model is chosen using information criteria and statistical properties of the model. VAR contains some of dummy variables discussed above that were needed to obtain normally distributed residuals. This is a vital assumption for the reliability of the Granger-causality test reported in the form of $\chi^2(k)$ statistic with p-value given in parenthesis.

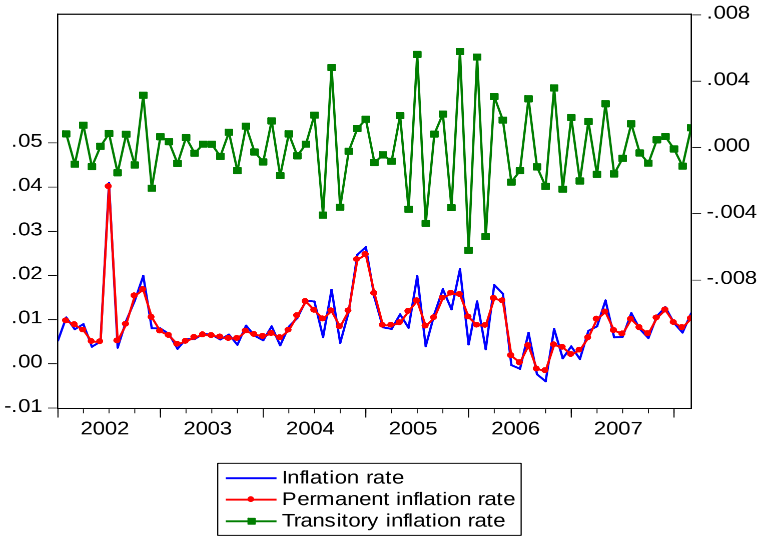
To find out how robust our results are to the behavior of inflation in the long and short run, the permanent-transitory decomposition of prices (log) is obtained under the assumption that its first difference, inflation, follows autoregressive process of order two. Both components are depicted together with prices in Graph 4.3. We may notice similar pattern of prices and its permanent component, while their difference, being transitory component, describes only short-run variability of prices. In the previous version of this paper [26] the Beveridge-Nelson decomposition [6] is used providing similar results.

First differences of permanent and transitory components represent permanent and transitory inflation respectively (Graph 4.4). These two time series are considered separately. Results of modeling permanent inflation will be given in details, while findings for transitory inflation will be briefly summarized.

Graph 4.3 Consumer price index, its permanent and transitory components



Graph 4.4 Inflation rate, permanent and transitory inflation rate



Three GARCH specifications are used to explain the behavior of permanent inflation. These are: restricted PGARCH(1,1) model, restricted PGARCH(1,1) model with permanent inflation lagged-three period and GARCH(1,1) model. Estimates are given below:

Restricted PGARCH(1,1)
(Model of permanent inflation I):

$$\hat{\pi}_{pt} = 0.008 + 1.012\pi_{pt-1} - 0.367\pi_{p_{t-2}}$$

(0.0007) (0.106) (0.111)

$$\hat{\sigma}_t = 0.25e^{-3} + 0.239|\varepsilon_{t-1}| + 0.719\sigma_{t-1}. \tag{4.3}$$

($0.25e^{-3}$) (0.128) (0.187)

Restricted PGARCH(1,1)
(Model of permanent inflation II):

$$\hat{\pi}_{pt} = 0.008 + 0.996\pi_{pt-1} - 0.347\pi_{p_{t-2}}$$

(0.0007) (0.114) (0.113)

$$\hat{\sigma}_t = 0.33e^{-4} + 0.215|\varepsilon_{t-1}| + 0.676\sigma_{t-1} + 0.040\pi_{pt-3} \tag{4.4}$$

($0.2e^{-3}$) (0.095) (0.138) (0.021)

GARCH(1,1)
(Model of permanent inflation III):

$$\hat{\pi}_{pt} = 0.008 + 0.942\pi_{pt-1} - 0.625\pi_{p_{t-2}} + 0.407\pi_{p_{t-3}}$$

(0.001) (0.106) (0.154) (0.112)

$$\hat{\sigma}_t^2 = 0.15e^{-5} + 0.306\varepsilon_{t-1}^2 + 0.573\sigma_{t-1}^2 \tag{4.5}$$

($0.7e^{-6}$) (0.153) (0.169)

Note: π_{pt} denotes permanent inflation. The BHHH algorithm is used in estimation. The Bollerslev-Wooldrige standard errors are calculated and given in (.) below the coefficient estimates. The mean equation of model (4.5) contains dummy variables for the following months: July, 2002, December, 2004 and January, 2005. Additional dummy variable for June, 2006 is included in the mean equation of models (4.3) and (4.4).

Models do not show signs of misspecification as confirmed by various specification tests reported in Table 4.3. All three models provide similar results: estimates of the mean equation do not differ significantly, while volatility equations capture almost identical effects of explanatory variables. Nevertheless, to make results more reliable we use all these models to generate uncertainty needed for Granger-causality testing.

Table 4.3 Specification tests for estimated models of permanent inflation

Model	Q(12)	$Q^2(12)$	JB	ARCH(4)	L
I	11.19(0.34)	6.80(0.74)	0.8(0.68)	3.0(0.57)	317.6124
II	12.30(0.27)	10.8(0.37)	1.3(0.54)	4.0(0.41)	319.8537
III	15.49(0.08)	6.13(0.79)	0.3(0.87)	3.8(0.44)	316.8911

Note: Test-statistics are explained in note below equation (4.2).

The results of the Granger-causality test between permanent inflation and associated uncertainty are presented in Table 4.4. The results are mostly in favor of causality running from permanent inflation to its uncertainty, suggesting that the Friedman-Ball hypothesis is relevant for the long-run inflation as well. There is now supporting evidence of causality running from uncertainty to permanent inflation. The null hypothesis that uncertainty does not Granger-cause permanent inflation cannot be rejected for *p*-values smaller than 5% and 6%. When standard inflation rate was considered the corresponding *p*-values were between 13% and 45% (Table 4.2). Thus, we may conclude that the Cukierman-Meltzer hypothesis has some empirical content for the permanent inflation in Serbia. The sum of estimated coefficients on lagged uncertainty in the equation for permanent inflation is negative. This implies that inflation uncertainty has a negative impact on the level of inflation at long horizon. Since the behavior of prices in the long-run is primarily determined by monetary policy, we may argue that monetary policy in Serbia has been relatively efficient during period of 2002-2008.

Table 4.4 Granger-causality test between permanent inflation and its uncertainty

VAR model	Order of VAR model	Ho: Permanent inflation does not Granger-cause uncertainty	Ho: Uncertainty does not Granger-cause permanent inflation
Model I	5	8.65 (0.13)	11.13 (0.05)
Model II	5	22.15 (0.00)	10.79 (0.06)
Model III	4	28.82 (0.00)	9.46 (0.05)

Note: See note below Table 4.2.

Transitory inflation was modeled within the similar framework. Only one-way causality is detected, stemming from short-run inflation to its uncertainty. In the short-run higher inflation invokes higher uncertainty, but uncertainty does not influence inflation significantly. Tentatively speaking, fiscal policy, responsible for the short-run variation in prices, has not been as efficient as monetary policy in stabilizing level of inflation.

5. MODELLING INFLATION RATE IN ROMANIA AND BULGARIA

Romania and Bulgaria have made remarkable progress in reducing their high inflation rates and bringing them down to the single-digit today. Hence, the change of the inflation pattern suggests that the issue of inflation-uncertainty relationship seems to be economically relevant for these two economies. Additionally, both level and variability of inflation rate might be influenced by oil and food price shocks that have become increasingly important since mid 2007.

We empirically investigated the dynamics of mean and volatility of monthly inflation rates in Bulgaria and Romania for period: January, 2001 – March, 2008 (87 observations). Inflation rate is calculated as the first difference of the logarithm of CPI. Data on CPI are taken from the IMF-IFS and WIIW databases. In both economies consumer price index is a unit-root process, while its first difference, inflation rate, is stationary (see Graph 5.1 and Table 5.1).

Graph 5.1 Level of CPI and inflation rate in Romania and Bulgaria

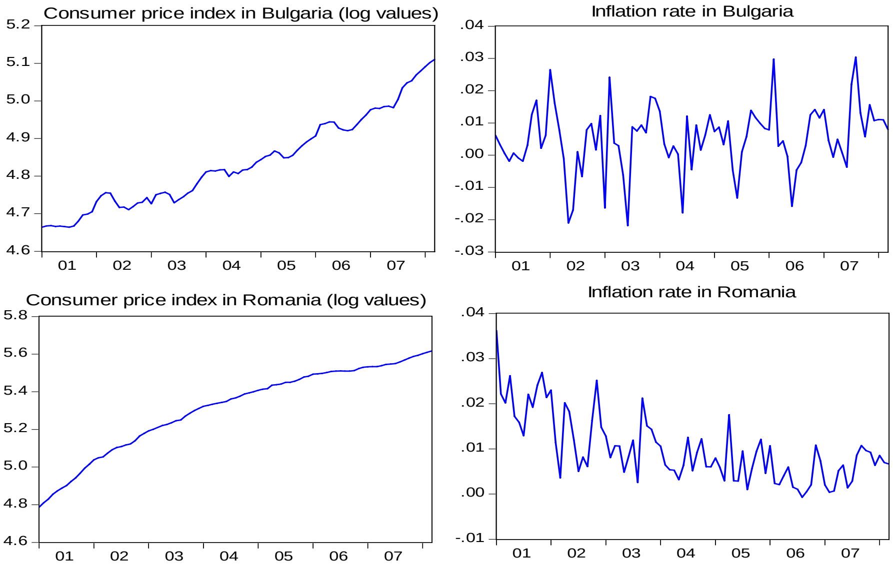


Table 5.1 Unit-root tests

	Augmented Dickey-Fuller test (ADF)		**Elliot-Rothenberg-Stock test (ERS)**	
Country	**Bulgaria**	**Romania**	**Bulgaria**	**Romania**
Unit root in the level of CPI	-1.84	-3.34	-1.82	-0.38
Unit root in the first difference of CPI (inflation rate)	-6.84	-6.33	-6.91	-6.00

Note: The number of lags in ADF test is chosen using general-to-specific approach starting with the maximum lag equal to 11 (the integer part of $12(87/100)^{0.25}$). The number of lags for the ERS test is chosen using SC criterion. All criteria applied suggest that the number of correction is equal to 1 for level of prices and 0 for its first difference. The discrimination between the null of a unit root presence and the alternative that the process is stationary is based on the model with constant and trend with the 5% critical value for ADF test –3.46 [23] and –3.08 for ERS test [14].

Inflation rate in Bulgaria

Bulgarian mean inflation rate is well described by AR(1) and AR(12) components. The chosen specification suggests that stochastic seasonal variations play important role in determining level of inflation rate. Four dummy variables (two impulse dummies and two transitory dummies) are included to capture the effects of non-standard observations. Volatility equation is estimated in the form of PGARCH(1,0) model with power parameter restricted to 2. Estimation results are given in equation (5.1) and they are depicted in Graph 5.2.

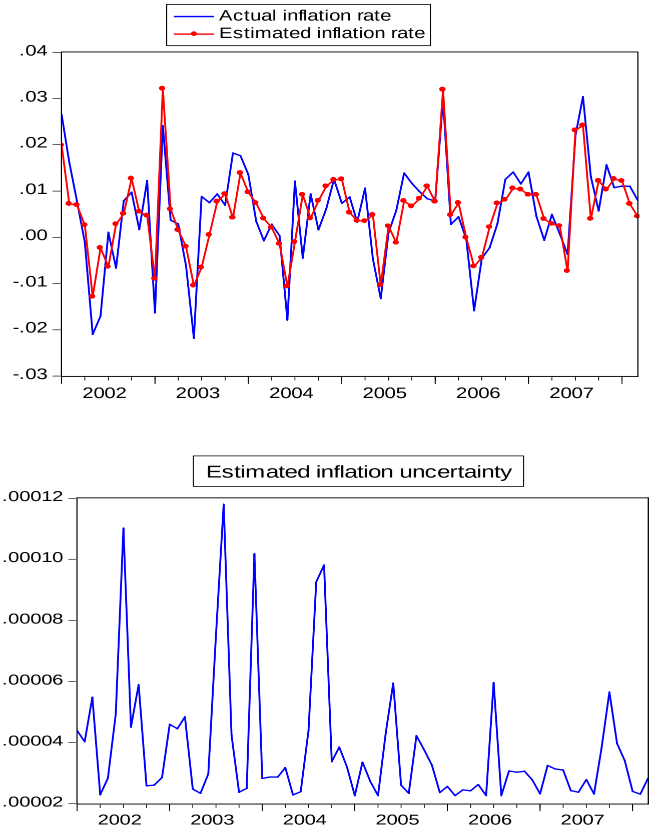
$$
\begin{aligned}
&\hat{\pi}_t^B = \underset{(0.006)}{0.007} + \underset{(0.092)}{0.363}\pi_{t-1}^B + \underset{(0.073)}{0.528}\pi_{t-12}^B \\
&\hat{\sigma}_t^2 = \underset{(0.6e^{-5})}{0.23e^{-4}} + \underset{(0.180)}{0.404}\left|\varepsilon_{t-1}\right| \qquad (5.1) \\
&JB = 0.59(0.74), ARCH(4) = 4.03(0.40), Q(12) = 5.26(0.87),\ Q^2(12) = 7.31(0.70).
\end{aligned}
$$

Note: π_t^B denotes inflation rate in Bulgaria. The BHHH algorithm is used in estimation. The Bollerslev-Wooldrige standard errors are calculated and given in (.) below the coefficient estimates. The mean equation contains four dummy variables that are defined as follows:

$$
VB1 = \begin{cases} 1 & \text{for } 2002:1 \\ -1 & \text{for } 2002:5 \\ 0 & \text{otherwise} \end{cases},\ VB2 = \begin{cases} -1 & \text{for } 2003:1 \\ 1 & \text{for } 2003:2 \\ 0 & \text{otherwise} \end{cases},
$$

$$
VB3 = \begin{cases} 1 & \text{for } 2006:2 \\ 0 & \text{otherwise} \end{cases},\quad VB4 = \begin{cases} 1 & \text{for } 2007:8 \text{ and } 2007:8 \\ 0 & \text{otherwise} \end{cases}.
$$

Graph 5.2 Estimated mean inflation and volatility in Bulgaria



Based on these results the Granger-causality test is performed. As reported in Table 5.2, there is strong evidence found in favor of Friedman-Ball hypothesis, implying that higher inflation rate raises inflation uncertainty in Bulgaria. The causality in opposite direction is not detected.

Table 5.2 Granger-causality test between inflation and its uncertainty in Bulgaria

VAR model between inflation and uncertainty	Ho: Inflation does not Granger-cause uncertainty	Ho: Uncertainty does not Granger-cause inflation
k=2	8.16(0.01)	0.10(0.95)
k=3	11.50(0.01)	4.27(0.23)

Note: The number of lags (*k*) in VAR model is chosen using information criteria and statistical properties of the model. VAR contains some of dummy variables from (5.1) that were included to obtain normally distributed residuals. The Granger-causality test is reported in the form of $\chi^2(k)$ statistic with *p*-value given in parenthesis.

Inflation rate in Romania

Dynamics of Romanian mean inflation rate is well captured by AR(1) and MA(12) components. The seasonality of mean inflation rate in Romania is of different nature than in Bulgaria. It is described by MA(12) element suggesting that seasonal variations do not persist throughout time. We also included three transitory dummy variables to take account of plus/minus blips. Volatility equation is modeled by simple ARCH(1) specification that performs statistically well, although relatively high value of Q^2 test-statistic implies that other specifications are also possible. Results are presented in equation (5.2) and they are depicted in Graph 5.3.

$$\begin{aligned} \pi_t^R &= \underset{(0.001)}{0.008} + \underset{(0.069)}{0.641}\pi_{t-1}^R + \varepsilon_t + \underset{(0.100)}{0.303}\varepsilon_{t-12} \\ \hat{\sigma}_t^2 &= \underset{(0.4e^{-5})}{0.12e^{-4}} + \underset{(0.154)}{0.299}\varepsilon_{t-1}^2 \end{aligned} \tag{5.2}$$

$$JB = 2.50(0.29), ARCH(4) = 6.85(0.14), Q(12) = 11.42(0.33),\ Q^2(12) = 17.02(0.07).$$

Note: π_t^R denotes inflation rate in Romania. The BHHH algorithm is used in estimation. The Bollerslev-Wooldrige standard errors are calculated and given in (.) below the coefficient estimates The mean equation contains three transitory dummy variables that are defined as follows:

$$VR1 = \begin{cases} -1 & \text{for } 2002:3 \\ 1 & \text{for } 2002:4 \\ 0 & \text{otherwise} \end{cases},\quad VR2 = \begin{cases} -1 & \text{for } 2003:8 \\ 1 & \text{for } 2003:9 \\ 0 & \text{otherwise} \end{cases},\quad VR3 = \begin{cases} 1 & \text{for } 2005:4 \\ -1 & \text{for } 2005:5 \\ 0 & \text{otherwise} \end{cases}$$

Results of the Granger-causality test again show one-way causality running from inflation to its uncertainty (Table 5.3). The causality stemming from inflation uncertainty to the level of inflation in Romania is not confirmed.

Graph 5.3 Estimated mean inflation and volatility in Romania

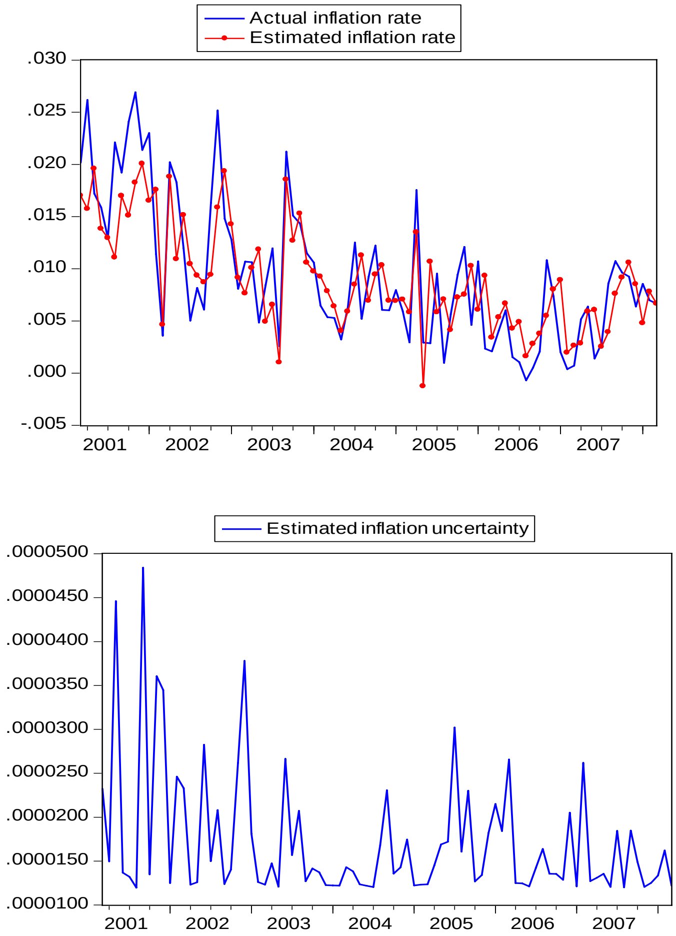


Table 5.3 Granger-causality test between inflation and its uncertainty in Romania

VAR model between inflation and uncertainty	Ho: Inflation does not Granger-cause uncertainty	Ho: Uncertainty does not Granger-cause inflation
k=2	20.45(0.00)	1.71(0.42)
k=6	14.65(0.02)	7.12(0.31)

Note: The number of lags (*k*) in VAR model is chosen using information criteria and statistical properties of the model. VAR contains dummy variables of equation (5.2) that are included to achieve normality of residuals. The Granger-causality test is reported in the form of $\chi^2(k)$ statistic with *p*-value given in parenthesis.

We may notice that estimated uncertainty of inflation rate in both Romania and Bulgaria differs significantly from inflation uncertainty derived for Serbia. This comes from different GARCH specifications accepted as statistically valid and used to generate this uncertainty. In the volatility equations of Romanian and Bulgarian inflation rates only lagged-one period error term appears as statistically important (ε_{t-1}^2 or $\left|\varepsilon_{t-1}\right|$), while equations for Serbian inflation rate additionally include volatility autoregressive term of order one (σ_{t-1} or σ^2_{t-1}). Consequently, estimated uncertainty of Serbian inflation rate exhibits higher degree of smoothness. On the other side, both Romanian and Bulgarian inflation uncertainty shows substantial short-term instability.

The long-run components of Romanian and Bulgarian inflation rates are extracted to determine characteristics of inflation-uncertainty relationship at the long and short horizon. As results obtained do not change conclusions already reported they are not presented.

6. CONCLUSION

This paper employs standard approach of GARCH modelling and VAR setup to consider relationship between inflation and inflation uncertainty in the Balkan region in period 2001-2008. Additionally, we have applied the signal-extraction decomposition of prices to find out what characterizes inflation-uncertainty relationship in the long and short run. There is strong evidence of causality running from inflation to its uncertainty that holds for all three economies considered (Serbia, Romania and Bulgaria). Although Romanian and Bulgarian inflation rates were lower than Serbian inflation rate with inflation volatility following different pattern than Serbian one, inflation uncertainty of these economies were significantly influenced by the level of inflation. Causality in reverse direction running from uncertainty to inflation was found only for the permanent component of prices in Serbia, such that increasing uncertainty reduces level of inflation in the long-run. Therefore, we may argue that monetary policy in Serbia has been relatively efficient in recent years.

LITERATURE

[1] Apergis, N., "Inflation, output growth, volatility and causality: evidence from panel data and G7 countries", *Economics Letters*, 83 (2004) 185-191.

[2] Baillie, R. , Chung, C. and Tieslau, M., "Analyzing inflation by the fractionally integrated ARFIMA-GARCH model", *Journal of Applied Econometrics*, 11 (1996) 23-40.

[3] Bell, W.R., "Signal extraction for non-stationary time series", *Annals of Statistics*, 12 (1984), 646-664.

[4] Ball, L., "Why does high inflation raise inflation uncertainty", *Journal of Monetary Economics*, 29 (1992) 371-388.

[5] Ball, L. and Cecchetti, S.G., "Inflation and uncertainty at short and long horizons", *Brookings Papers on Economic Activity*, 1 (1990) 215- 245.

[6] Beveridge, S. and Nelson, C.,"A new approach to decomposition of economic time series into permanent and transitory components with particular attention to measurement of the business cycle", *Journal of Monetary Economics*, 7 (1981) 151-174.

[7] Bollerslev, T., "Generalized autoregressive conditional heteroskedasticity", *Journal of Econometrics*, 31 (1986) 307-327.

[8] Caporale, T. and McKiernan, B., "High and variable inflation: Further evidence on the Friedman hypothesis", *Economics Letters*, 54 (1997) 65-68.

[9] Chen, S.W., Shen, C.H. and Xie, Z., "Nonlinear relationship between inflation and inflation uncertainty in Taiwan", *Applied Economics Letters*, 13 (2006) 529-533.

[10] Cosimano, T. and Jansen, D., "Estimates of the variance of US inflation based upon the ARCH model", *Journal of Money, Credit and Banking*, 20 (1988) 409-421.

[11] Cukierman, A., *Central Bank Strategy, Credibility, and Independence*, MIT Press, Cambridge, 1992.

[12] Cukierman, A. and Meltzer, A.H., "A theory of ambiguity, credibility, and inflation under discretion and asymmetric information", *Econometrica*, 54 (1986) 1099-1128.

[13] Daal, E., Naka, A. and Sanchez, B., "Re-examining inflation and inflation uncertainty in developed and emerging countries", *Economics Letters*, 89 (2005) 180-186.

[14] Elliott, G., Rothenberg, T.J. and Stock, J.H., "Efficient Tests for an Autoregressive Unit Root", *Econometrica*, 64 (1996), 813 – 836.

[15] Enders, W., *Applied Econometric Time Series*, 2nd edition, Wiley, New York, 2004.

[16] Engle, R.F., "Estimates of the variance of U.S. inflation based on the ARCH model", *Journal of Money, Credit and Banking*, 15 (1983) 286-301.

[17] *EVIEWS6 User's Guide,* Quantitative Micro Software, CA, 2007.

[18] Fountas, S., "The relationship between inflation and inflation uncertainty in the UK: 1885-1998", *Economics Letters*, 74 (2001) 77-83.

[19] Friedman, M., "Nobel lecture: Inflation and unemployment", *Journal of Political Economy*, 85 (1977) 451-472.

[20] Grier, K.B. and Perry, M.J., "On inflation and inflation uncertainty in the G7 countries", *Journal of International Money and Finance*, 17 (1998) 671-689.

[21] Holland, A.S., "Inflation and uncertainty: Tests for temporal ordering", *Journal of Money, Credit and Banking*, 27 (1995) 827-837.

[22] Hwang, Y., "Relationship between inflation rate and inflation uncertainty", *Economics Letters*, 73 (2001) 179-186.

[23] MacKinnon, J., "Critical values for cointegration tests", in *Long-Run Economic Relationships: Readings in Cointegration* (eds. R. F. Engle and C. W.J. Granger), Oxford University Press, Oxford, 267-276.

[24] Maravall, A., "An application of the TRAMO-SEATS automatic procedure; direct versus indirect adjustment", *Computational Statistics and Data Analysis*, 50 (2006) 2167-2190.

[25] Mladenovic, Z., "Modelling economies in transition: Econometrics of structural break" in *Privatization in Serbia: Evidence and Analysis* (ed. B. Cerovic), Faculty of Economics, Belgrade, 107-122, 2006.

[26] Mladenovic, Z., "Relationship between inflation and inflation uncertainty: the case of Serbia", *Proceedings of the 8th Balkan Conference on Operational Research*, Zlatibor, Belgrade, (2007), http://balcor.fon.bg.ac.yu/.

[27] *RATS User's Guide, Version 6*, ESTIMA, Evanston, IL, 2006.

[28] Tevfik, N. and Perry, M., "Inflation, inflation uncertainty, and monetary policy in Turkey: 1960-1998", *Contemporary Economic Policy*, 18 (2000) 170-180.

[29] Thornton, J., "The relationship between inflation and inflation uncertainty in emerging market economies", *Southern Economic Journal* 73 (2007) 858-870.

[30] Tsay, R., *Analysis of Financial Time Series*, 2nd edition, Wiley, New York, 2005.