ELIT
Economic Laboratory Transition
Research Podgorica

Montenegrin Journal of Economics

Lukianenko, I., Nasachenko, M., Tokarchuk, T. (2022), "Inflation Expectations Investigation Using Markov Regime-Switching Autoregression",
Montenegrin Journal of Economics, Vol. 18, No. 1, pp. 19-29.

Inflation Expectations Investigation Using Markov Regime-Switching Autoregression

IRYNA LUKIANENKO[1], MARIIA NASACHENKO[2] and TARAS TOKARCHUK[3]

[1] Doctor of Economic Sciences, Professor, Head of the Department of Finance at National University of Kyiv-Mohyla Academy, e-mail: iryna.lukianenko@ukma.edu.ua
[2] Ph.D. Student, National University of Kyiv-Mohyla Academy, e-mail: m.nasachenko@ukma.edu.ua
[3] Candidate of Economic Science, Senior Lecturer, National University of Kyiv-Mohyla Academy, Deputy Head of Division – Head of Macroeconomic Forecasting Unit, Monetary Policy and Economic Analysis Department at National Bank of Ukraine, e-mail: Taras.Tokarchuk@bank.gov.ua

ARTICLE INFO

Received May 05, 2021
Revised from June 10, 2021
Accepted July 12, 2021
Available online March 15, 2022

JEL classification: C34, E42, E47, E58

DOI: 10.14254/1800-5845/2022.18-1.2

Keywords:

Markov switching autoregression,
inflation expectations,
monetary policy,
inflation,
macroeconomic instability,
crisis.

ABSTRACT

The purpose of the article is to estimate the regimes of low, moderate and high volatility of inflation expectations in Ukraine during the periods of macroeconomic instability and crises to find how economic agents' projections change under the different circumstances. Besides that, study aimed at extensive analysis of the influence of monetary policy and overall situation on the market in general on presuppositions of subjects of economic activity regarding the further dynamics of prices. Based on wide and comprehensive literature review the Markov switching autoregression with three regimes was used to analyze the probabilities of each of the types of volatility. This approach allows to define the likelihoods of transition from one regime to other and influence of chosen indicators, such as key policy rate, CPI, index of real wage on inflation expectations under low, moderate and high volatility mode. The results show that the high volatility of inflation expectations was the most probable on the sample from January 2013 to August 2020 due to the macroeconomic instability in the country caused by the crisis and global lockdown. Moreover, regime of moderate fluctuations is the longest one and lasts about 5 months in comparison to high and low volatility regimes, which continued only for 4 and 1 months respectively. Findings confirm that during considerable fluctuation of inflation expectations, which prevailed over the research period impact of the key policy rate on economic agents' judgments about the future prices was the most notable.

INTRODUCTION

The change of monetary regime in Ukraine has become a heated debate among policymakers and scientist. The switch from the fixed exchange rate to inflation targeting shifted the focus of attention to interest rate and inflation expectations channels of transmission mechanism. At the first stage, due to

the change of the key policy rate, the National Bank determines the level of short-term interest rates on the interbank market. These, in turn, affect aggregate demand and inflation through various channels, in particular through changes in the inflation expectations of the population and business. Therefore, managing inflation expectations becomes effective by increasing confidence in the regulator's actions if it pursues a clear and consistent policy of inflation targeting. In time of transition to the inflation targeting regime during a period of high or highly volatile inflation, ordinary citizens distrust the new regime and, accordingly, their inflation expectations improve gradually. One of the important tasks of the inflation targeting regime is to anchor inflation expectations, what requires a detailed study of changes in the judgments of economic agents about future price increases. The central bank, which pursues a policy of inflation targeting, influences inflation expectations to ensure the confidence of businesses and individuals in own force to return inflation to the target range in the medium term. Under such conditions, inflation does not create obstacles to sustainable economic growth. Inflation expectations determine long-term inflation trends, which are taking into consideration in decisions:

- by business – in relation to investments, loans, prices for own products and resources used in its creation;
- by population – on the distribution of disposable income for current consumption and savings, as well as on the optimal form of such savings.

Monetary policy under the regime of inflation targeting requires to use forward-looking guidance in order to estimate how the situation will change in the future to react reasonably now. This is possible only with the use of models of varying complexity to assess all interactions between macroeconomic indicators both retrospectively and in the future. The econometric models allow to estimate the numerical dependence of inflation expectations on chosen macroeconomic indicators, such as key policy rate as a main monetary policy instrument, consumer price index, real incomes etc. Besides that, it is paramount to evaluate the likelihoods of each type of volatility and changeovers from one to another.

Over and above, inflation expectations are important part of the transmission mechanism, so it is crucial and essential to conduct a deep study on how powerfully monetary policy may influence on them; and determine probabilities of low, moderate and high volatility regimes to reveal how judgements of population and enterprises about the price level behave under the different circumstances with the employing complex econometric tools.

The research purpose is to determine the regimes of low, moderate and high volatility of inflation expectations and analyze the degree of influence of key policy rate, consumer price index and index of real wage on them applying switching Markov autoregression model. There are two research questions that arise from the goal of the investigation: (a) What were the probabilities of each of the regime (low, moderate and high volatility) during the research period? (b) How strongly does central bank policy affect inflation expectations?

1. LITERATURE REVIEW

Various models are commonly employed to analyze the dynamic of economic and financial time series. Classical linear models over the past two decades have receded into the background, in contrast, interest has shifted to nonlinear econometric tools (Teräsvirta, 2005). This tendency continued, because linear models were unable to represent numerous nonlinear patterns such as volatility clustering, asymmetry and amplitude dependence (Kuan, 2002). Moreover, nonlinear forecasting also gain popularity, researchers employed smooth transition autoregressive models (Lundbergh and Teräsvirta, 2000), neutral network models (Zhang, Patuwo and Hu, 1998), etc.

The Hamilton's (1989) Markov switching model is one of the earliest examples of analysis of the economic time series using nonlinear tool with multiple equations, which allows to estimate the behavior in different regimes. The study explored the possibility of discrete shifts of real GNP from recession to growth. Year later Hamilton (1990) performed expectation-maximization algorithm for obtain parameter estimates of processes with discrete shifts in autoregressive parameters modelled as Markov switching to discover how exogenous economic events influence financial data. Worthwhile study based on this

methodology also developed by the Simon (1996), who suggest two-regime specification of the model of inflation supplemented by the output gap to get some insights about the behavior of the expectations, which may be rational for imperfectly informed observers.

Next decades Markov Switching models became widely used for analyzing prices, inflation, exchange rates and unemployment, for instance from the point of view of the expectations the MS estimation of a Philips curve discussed in Pagliacci and Barraez (2010) distinguishes between "normal" and "rational expectations" regime. In the first regime of this model, economic agents form own expectations based on the past tendencies of indicators, such as exchange rate, money creation, output gap, etc., in contrast, in the second regime agents systematize their expectation relying on forecasts of economic growth, inflation, overall situation in the country. Before long, Bialowolski, Zwiernik and Zochowski (2011) investigated inflation in Poland during the period of economic transition with MS framework to achieve delimitation, where process of disinflation took place. The other successful attempt of testing hypothesis about long swings in exchange rates applying Markov regime switching model was made by Klaassen (2005), no less considerable results focused on inflation expectations modeling as a Markov chain described in Kocherlakota (2016). Valuable conclusions on the probability of inflation returning to high-volatility and high-persistence regimes were gained in Nalewaik (2015) with the Markov switching approach, which recognized the transition of the regime much faster than surveys and analysts on the financial market. Recent years, MS approach became widely used also for labour market estimation, Oliskevych and Lukianenko (2020) revealed that unemployment rate in UE countries behaved asymmetrically over the business cycles. Therefore, Markov switching models are broadly employed for analyzing monetary policy, labor market, stock market, etc. to formally describe its nonlinear nature.

The Markov switching models may use in combination with the others, for example to estimate the WTI crude oil volatility it was applied with traditional GARCH and EGARCH approaches (Runfang, Jiangze, Xiaotao, 2017). MSGARCH model prevail the simple GARCH and EGARCH models from the standpoint of stability and adequacy, besides that RMSE calculated on the basis of model with Markov switching is smaller on about 66.7% when T is 12 months. Alternatively, the experience of Markov switching VAR successfully performed in Uzoma and Florence (2016) to investigate regime change in the stock market price. MSVAR with two regimes detected shifts in return series and gave possibility to consider the sudden changes in the stock data by using exogenous variables. The similar proceedings executed by Holm-Hadula and Hubrich (2017) based on regime-switching VAR found that oil price fluctuations are usually led to limited adjustments in inflation and economic activity.

Since, the entire research is dedicated to determine the regimes of low, moderate and high volatility of inflation expectations taking into account the degree of influence of key policy rate, consumer price index and index of real wage, based on detailed review of described literature it became comprehensible that the most effective way is to implement Markov switching autoregression with several regimes to estimate how the transition of monetary regime and macroeconomic instability effected the inflation expectations.

2. DATA AND METHODOLOGY

The use of modeling tools to analyze the behavior of economic and financial time series is becoming steadily more important. Linear time series models (regressions, AR, MA, ARIMA) in modern research are increasingly being replaced by nonlinear ones. This is due to the fact that the cyclical nature of the economy generates transitions from resistant periods of economic growth to recessions, which are usually characterized by significant volatility of key macroeconomic indicators. Therefore, with a linear model it is impossible to reproduce all the processes occurring in the economy, and there is a need to use nonlinear modeling tools instead. Notwithstanding the advantages of nonlinear models, they have own limitations such as cumbersome implementation, lack of flexibility, because it developed to estimate nonlinear processes and cannot pretend to be universal, insufficient for short time intervals and a small number of lags (DelSole, 2000).

There are several types of models with switches (Fig. 1), namely the classic regressions with switches (Switching Regression) are divided into two large groups: models with simple regime switching (Simple

Switching) and Markov (Markov Switching). In addition, each of these models can contain a dynamic component (Dynamic models), so in the framework of regressions with regime switching also distinguish Markov Switching AR and Simple Switching AR.

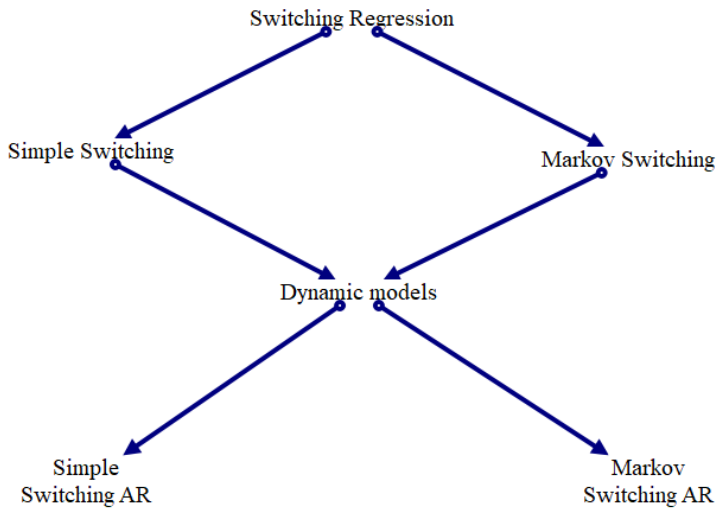

Figure 1. Classification of the switching models

The main difference between Markov switching and simple is:

- the current state in the model with simple switching depends on all previous states;
- the current state in the model with Markov switching depends only on the state of the previous period

In addition, a distinctive feature of the Markov model with regime switching is the use of the first-order Markov process to calculate the probabilities of transition from one regime to another. According to Markov's first order assumption, the probability of being in the regime depends on the previous state, so

$$P(s_t = j | s_{t-1} = i) = p_{ij}(t) \qquad (1.1)$$

These probabilities are considered independent of time, so $p_{ij}(t) = p_{ij}$ for all t, however, this restriction is not mandatory. Probabilities can be represented as a matrix of transitions:

$$p(t) = \begin{bmatrix} p_{11}(t) & \dots & p_{1M}(t) \\ . & \dots & . \\ p_{M1}(t) & \dots & p_{MM}(t) \end{bmatrix}, \qquad (1.2)$$

where the ij-th element represents the probability of transition from regime i in period t-1 to regime j in period t.

The probabilities can be parameterized using a logistic polynomial as in the case of simple models with a change of regimes. Each row of the transition matrix defines a complete set of conditional probabilities, so there is a separate polynomial specification for each i-th row of the matrix:

$$p_{ij}(G_{t-1}, \delta_i) = \frac{\exp({G_{t-1}}'\delta_{ij})}{\sum_{s=1}^{M} \exp({G_{t-1}}'\delta_{is})} \qquad (1.3)$$

where j=1,...,M, i=1,...,M with the normalizations $\delta_{iM} = 0$.

Markov models with regime switching are generally estimated with constant probabilities, so G_{t-1} contain only one constant. Hamilton's (1989) model for GDP is a classic example of the model with constant transition probabilities. The application of logistic parameterized probabilities that change over

time is also possible, as proved by the example of the two-state model in the study of Diebold, Lee and Weinbach (1994).

One of the properties of the Markov model with switches is the ability to recursively estimate the probabilities of transition from one regime to another based on the right side of the equation:

$$l(\beta,\sigma,\delta) = \sum_{t=1}^{T} log\left\{\sum_{m=1}^{M} \frac{1}{\sigma_m}\phi\left(\frac{y_t - \mu_t(m)}{\sigma(m)}\right) \times P(s_t = m|\zeta_{t-1},\delta)\right\} \quad (1.4)$$

where β,σ,δ – parameters, which determine the transition probabilities; ϕ – standard normalized density function; ζ_{t-1} – information component in the period t-1.

Each recursion step begins with filtered estimates of the probabilities of transition from regime to regime in the previous period. Given the filtered probabilities $P(s_t = m|\zeta_{t-1})$ recursion can be performed in 4 stages:

– At the first stage, with the help of the basic rules of probability theory and the Markov transition matrix, forecasts regarding the probabilities of transition one step forward are formed:

$$P(s_t = m|\zeta_{t-1}) = \sum_{j=1}^{M}(s_t = m|s_{t-1} = j) \times P(s_{t-1} = j|\zeta_{t-1}) = \sum_{j=1}^{M} p_{jm}(G_{t-1},\delta_j) \times \quad \times P(s_{t-1} = j|\zeta_{t-1}) \quad (1.5)$$

– Next, the obtained one-step probability predictions are used to generate pooled density functions for the next period for data and regimes in period t:

$$f(y_t, s_t = m|\zeta_{t-1}) = \frac{1}{\sigma_m}\phi\left(\frac{y_t - \mu_t(m)}{\sigma(m)}\right) \times P(s_t = m|\zeta_{t-1}) \quad (1.6)$$

– Probability contributions for the current period (t) are calculated by summing the combined probabilities by unobserved states in order to obtain the marginal distribution of the observed data:

$$L_t(\beta,\gamma,\sigma,\delta) = f(y_t|\zeta_{t-1}) = \sum_{j=1}^{M} f(y_t, s_t = j|\,\zeta_{t-1}) \quad (1.7)$$

– At the last stage, the probabilities are filtered based on equation (1.6) to update the predicted probability values one step further:

$$P(s_t = m|\zeta_{t-1}) = \frac{f(y_t, s_t = m|\zeta_{t-1})}{\sum_{j=1}^{M} f(y_t, s_t = j|\,\zeta_{t-1})} \quad (1.8)$$

These steps are repeated sequentially to calculate the probabilities of transition from mode to mode for each period t=1, …, T. All that is needed for the procedure is the initial filtered probabilities, $P(s_0 = m|\zeta_0)$, or the initial one step forward probabilities $P(s_1 = m|\zeta_0)$.

The study was performed on monthly data from January 2013 to August 2020, and has 92 observations in total. The data are retrieved from NBU statistics on Macroeconomic Indicators and Financial Sector Statistics.

2. EMPIRICAL RESULTS

The review of the literature showed the need of use linear econometric models with nonlinearities for empirical research, especially in the case of assessing the consequences of economic and institutional transformations, such as shift of the monetary regime, stock market price (Uzoma and Florence, 2016) and exchange rate (Klaassen, 2005) fluctuations etc. The developed Markov model has three equations, each of which characterizes a regime with certain type of volatility of the dependent variable. In final specification inflation expectations (Infl_exp) are dependent on own previous value, NBU key policy rate (KPR), index of real wage (IRW) and consumer's price index (CPI). Regime specific error variances are available for each of the equations to take into account peculiarities of all three periods. The results of the estimation of the Markov model with regimes switching are presented in the Table 1.

Table 1. The results of the estimation of the Markov model with regime switching

Equation specification	
Regime 1	DW stat = 1.76 Stat. Jarque-Bera = 3.022, P(J-B) = 0.22
$Infl\_exp_t = \underset{(132,9)}{9{,}69\alpha_t} + \underset{(125,9)}{0.95 infl\_exp_{t-1}} - \underset{(-111,4)}{1{,}05 D(KPR_{t-1})} - \underset{(-124,4)}{0{,}63 D(IRW_{t-1})} + +0{,}57 D(CPI_t)$ (18,78) LOG(SIGMA) = -4.38; $\sigma = \exp(-4.38) = 0{,}12$	
Regime 2	
$Infl\_exp_t = \underset{(126,4)}{9{,}83\alpha_t} + \underset{(125,9)}{0.95 infl\_exp_{t-1}} + \underset{(9,8)}{0{,}14 D(KPR_{t-1})} - \underset{(-2,9)}{0{,}04 D(IRW_{t-1})} + +0{,}1 D(CPI_t)$ (3,9) LOG(SIGMA) = 0.17; $\sigma = \exp(0.17) = 1{,}18$	
Regime 3	
$Infl\_exp_t = \underset{(68,3)}{8{,}27\alpha_t} + \underset{(125,9)}{0.95 infl\_exp_{t-1}} + \underset{(16,0)}{1{,}59 D(KPR_{t-1})} + \underset{(2,0)}{0{,}06 D(IRW_{t-1})} - -0{,}04 D(CPI_t)$ (-0,7) LOG(SIGMA) = -0.53; $\sigma = \exp(-0.53) = 0{,}59$	

Source: author's calculations in E. VIEWS 10

where $Infl\_exp_t$ – inflation expectations for the next 12 months, in %, CPI_t – consumer price index, in %, KPR_t – NBU key policy rate, in p.p., IRW_t – index of real wage, D – difference operator, z-Statistic in parentheses.

There are three estimated equations, which represent regimes with low, moderate and high volatility of inflation expectations. Type of volatility is defined on the base of variance, calculated from the log(sigma), which is different for all three regimes. Consequently, first regime describes low volatility ($\sigma = 0{,}12$), second – high ($\sigma = 1{,}18$), third – moderate ($\sigma = 0{,}59$). This feature of Markov switching AR models allows to gain additional information from investigations of two and more equations simultaneously, because each of them distinguished by the own power of volatility.

Lagged value of the inflation expectations, which is common for all the regimes, is used due to the fact that economic agent's projections are strongly anchored to the previous judgments about the further trends. In other words, analytics regarding future prices tend to be based on the past conclusions, especially if economic situation in the country mostly unstable and it is significant uncertainty about the inflation in the next periods. An increase of inflation expectations by 1% in previous period leads to hike of current expectations on the subject of prices on 0,95%. Under the inflation targeting NBU key policy rate is the main instrument of monetary policy, which becomes an indicator for not only of policymaker's estimations of the macroeconomic situation, but also of central bank's medium-run inflation vision. Besides that, market players, analytics, banks, households normally form their prices related expectations based on current key policy rate. In the line with the economic theory increase of the key policy rate on 1 percentage point in the first regime with lowest volatility provoke decrease of inflation expectations by 1.05%. Under the second and third regimes key policy rate hike by 1 percentage point cause increase of inflation expectations by 0,14% and 1,59% respectively. A step up in inflation expectations during regimes 2 and 3 in contrast to downward tendency in the first regime as a response to key policy rate increase is due to the high and moderate volatility of dependent variable. Periods of the mostly high volatility occurred in the time of crisis, macroeconomic instability and institutional transformations, which took place in Ukraine between 2013 and 2020. Index of real wage indirectly represents the influence of economic growth on inflation expectations. Growth of real wage means increase of consumption in the next period and demand as a result, which further can provoke higher prices. In regimes with low and high volatility increase of index of real wage causes fall off of inflation expectations by 0,63% and 0,04% respectively. During the short period of low volatility of inflation expectation inverse relationships between variables could be explained by general stable macroeconomic environment. Over a time of stability eco-

nomic agents percept that the situation will be the same for a long period in the future and their incomes continue to grow at insignificant price rise. Hereby, the effect of index of real wage on inflation expectation is positive (0,06%) in the regime of moderate volatility. The interaction between consumers price index and inflation expectation according to the economic theory should be strong and positive, because increase of prices prompt firms, households, banks, analytics to expect continuation of the tendency. This proved by the modeling results, at regimes of low and high volatility inflation expectations change by 0,57% and 0,1% accordingly. At the same time, hike of CPI under the regime of average volatility decrease inflation expectation by 0,04%. So, it means that moderate volatility percept by the economic agents as more stable time then the periods with definitely lower changeability of inflation expectations.

Adequacy and quality of the Markov model was proved by the wide range of methods. Firstly, Darbin Watson statistic, which is equal to 1.76 falls into the interval between critical points d_u=1.751 and 4-d_u=2.249 under the level of significance α=0.05., what confirms the absence of autocorrelation of residuals. Secondly, Jarque-Bera statistic shows that residuals of the model are normally distributed with the probability of 22%. Thirdly, all the coefficients are statistically significant, except one, which is near the CPI in the Regime 3; this might be due to the fact that in periods with moderate volatility inflation expectation deeply depends on fundamental macroeconomic changes and signals, such as NBU's decisions regarding key policy rate, economic growth, etc.

Probabilities of moving from one regime to other are shown in Table 2. The switch from first regime to second possible with the highest probability equal to 99%. Crises and macroeconomic instability in Ukraine caused high likelihood of transition from regime of low volatility to the one with high fluctuations of inflation expectations. Simultaneously, there is a probability of 74% to stay in high volatile mode, because during the 2013-2020 two crises took place. Both of them accompanied by high fluctuations of inflation expectations, macroeconomic political crisis 2013-2015 brought up inflation to almost 60% per year, after that switch of the monetary regime was needed to curb price increases. Short period of stability interrupted at the end of 2019 with start of the global crisis caused by the lockdown, which also provoked decline in economic activity and deterioration of expectations. The probability of 80% to stay in third regime with the moderate volatility allows to assume high potential for anchoring Ukraine's inflation expectations on some middle level. Above average probability to have restrained fluctuations indicates that in non-crisis periods economic agents give rational judgement about future prices. Along with that, long domination of low volatility mode possible only on 0.02%, what prove the problem of continuous unstable macroeconomic environment in the country. The Ukrainian economy is characterized by cyclicality, because the most typical transition is from low to high volatility, so every steadiness stage is followed by crisis with large changeability of prices and inflation expectations.

Table 2. Transition matrix

№ of regime	1	2	3
1	0.0002	0.99	5.02E-05
2	0.18	0.74	0.07
3	0.19	0.0002	0.8

Source: author's calculations in E. VIEWS 10

Despite the fact that instable and unsteady times provoked by the domestic political crisis in 2013 and global lockdown in 2020, moderate volatility regime is the lengthiest. Inflation expectations fluctuate normally in average for 5 months; two other regimes with high and low volatility lasts in general for 1 and 4 months respectively (Table 3). Economic agent's perceptions in relation to the price level remain lowly volatile no longer than one month, because the market adapts to the current conditions and improve the suppositions regarding the future inflation. Almost 4 months is the duration of high oscillations of inflation expectations, what confirms the significant instability and uncertainty caused by the number of reasons, such as war, structural reforms, political vicissitudes, global pandemic crisis, etc.

Table 3. Constant expected durations of regime

№ of regime	1	2	3
Months	1.0002	3.92	5.22

Source: author's calculations in E. VIEWS 10

The obtained probabilities and durations of dominance of each regime over time may be graphically illustrated (Fig. 2). During the study period, the most probable was the onset of a regime of high volatility of inflation expectations, which is commonly confirms by the historical data due to the real rise of market disturbances on the indicated periods. At the same time, periods of high probability to stay in the moderate mode were clearly visible in the middle of 2017 and 2019; those time intervals characterized by positive dynamics of almost all economic indicators, in both cases inflation together with inflation expectations decreased in consequence of reasonable monetary policy of the NBU. The low volatility regime is possible only with the probability of 20% on all the time line due to the conflicting sentiments of economic agents and crises phenomena, what contributed to divergent perceptions of overall economic situation. Over and above, in conditions of transition from one monetary policy framework to another, especially in times of extremely high and volatile inflation, it is a conventional behavior of banks, households, businesses, financial analysts to judge pessimistically about the prices in order to take into account market risks. In response to the ambiguous market situation, businesses often try to protect their own activities from bankruptcy caused by insolvency through the rising prices for raw materials, materials, etc. by (a) reducing their own costs and hence solvent demand, (b) increasing unit sales prices, (c) layoffs, (d) increasing the manufacturability of production, if there is an opportunity for capital investment. The most typical reactions for the crises in Ukraine were dramatic rise of prices due to the devaluation of national currency, layoffs of service workers owing to lockdown and even closure of structural units to avoid complete bankruptcy. Forasmuch, constant expected durations for the regimes 2 and 3 may uphold the fact of continuous crisis in the country, because period of high and moderate volatility of inflation expectations were significantly longer than times of stability.

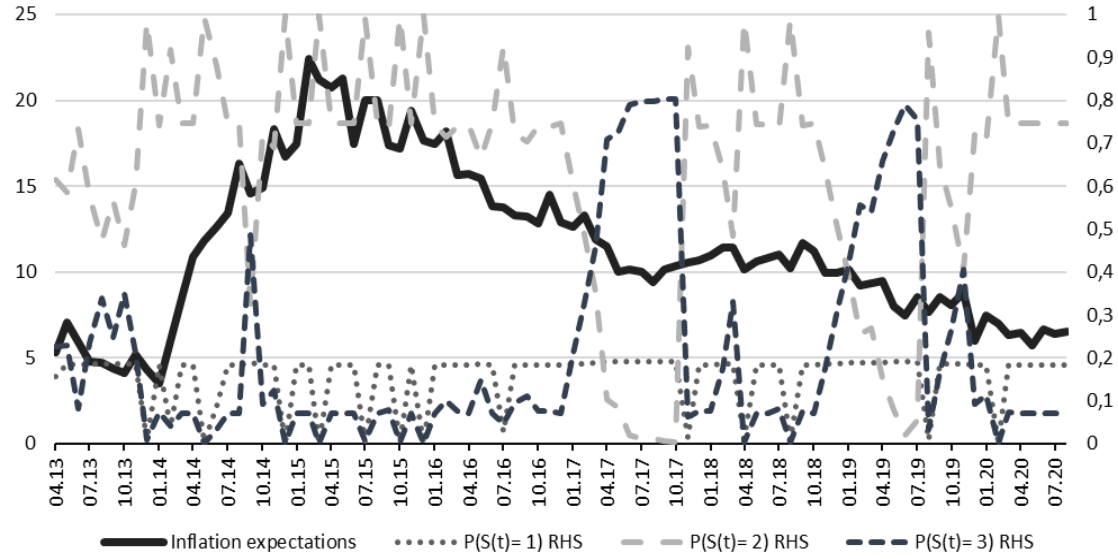

Figure 2. Graphical representation of regime probabilities for inflation expectations

Source: author's calculations in E. VIEWS 10

Inflation expectations reflect the interaction of a large number of factors, in particular in this case it is possible to analyze the dependence of the probability of occurrence of a regime on the threads of the NBU key policy rate, real wage index and consumer price index. Approach based on the Markov chain

allows to identify the probabilities of high, low or moderate volatility, but fluctuations almost always are the results of uncontrolled crises phenomena or policy, which government applied. Designed autoregression with Markov switching estimate the influence of fundamental instruments supervised by government, such as key policy rate from the one side and economic indicators which reflect unexpected changes in the market situation, such as CPI from the other. Referring to that, connection between the trend of the indicator and the probability being in the certain regime exist (Table 4). Ukraine's economy was uncertain and mutable, what fully explain the small probability (18-19%) to have low volatility of inflation expectations on all the research sample. The beginning of the revolution of Dignity in 2014 had led to huge hike of the probability to be in high volatile mode, because of crisis, which started after. The trend analysis shows that upward tendency of key policy rate, lagged inflation expectations, CPI take place, however index of real wage is declining due to the devaluation of exchange rate, what later caused increase of prices and as a result tight monetary policy. Only in 2016 the crisis caused by political events was brought under control, not least due to the transition of the National Bank to inflation targeting, but despite this it had considerable economic consequences, so likelihood of high volatility remained significant. During the 2017-2018 NBU kept key policy rate relatively high to slow down the prices and cope up with uncertainty, which still was weighty enough, considerable oscillations of inflation expectations were probable on 73-98%. Nevertheless, from March to October in 2017 moderate volatility of inflation expectations was also possible with probability of 46-80%, what confirms gradual recovery from the crisis partially reflected as increase of index of real wage. The implementation of inflation targeting has yielded results, and with decreasing inflation in 2019, the level of key policy rate has declined, but the volatility of inflation expectations remains significant with a probability of 54-75% to have moderate fluctuations. In 2020, due to the global blockade and uncertainty about future opportunities to support business, have an uninterrupted supply of raw materials and goods from abroad, organize regular contact with customers, conduct business trips, etc., the probability of high volatility of inflation expectations increased to 74-99%. At that time, policymakers were aimed at supporting the country's economy that has already suffered from the effects of slowed economic activity, respectively, the National Bank of Ukraine lowered the key policy rate to the historical minimum of 6 percentage points.

Table 4. Detailed characteristics of each of the regime

№ of regime	*Periods*	*Probability being in regime*	*Characteristics*	
			Indicator (variable)	*Trend (up/down/etc.)*
1 (with low volatility)	04.13-07.20	18-19%	Inflation expectations	Upward ↑, Downward ↓
			Key policy rate	Upward ↑, Downward ↓, Upward ↑, Downward ↓
			CPI	Upward ↑, Downward ↓
			Index of real wage	Downward ↓, Upward ↑
2 (with high volatility)	01.14-05.14	74-99%	Inflation expectations	Upward ↑
			Key policy rate	Upward ↑
			CPI	Upward ↑
			Index of real wage	Downward ↓
	12.14-12.16	66-99%	Inflation expectations	Upward ↑, Downward ↓
			Key policy rate	Upward ↑, Downward ↓
			CPI	Upward ↑, Downward ↓, Upward ↑
			Index of real wage	Downward ↓, Upward ↑
	11.17-10.18	73-98%	Inflation expectations	Upward ↑, Downward ↓, Upward ↑
			Key policy rate	Upward ↑
			CPI	Downward ↓
			Index of real wage	Downward ↓
	02.20-08.20	74-99%	Inflation expectations	Downward ↓, Upward ↑
			Key policy rate	Downward ↓
			CPI	Downward ↓, Upward ↑
			Index of real wage	Downward ↓, Upward ↑

3 (with moderate volatility)	09.14	48%	Inflation expectations	Relatively high
			Key policy rate	Moderate
			CPI	Moderate
			Index of real wage	Relatively low
	03.17-10.17	46-80%	Inflation expectations	Downward ↓, Upward ↑
			Key policy rate	Downward ↓, Upward ↑
			CPI	Downward ↓, Upward ↑, Downward ↓
			Index of real wage	Upward ↑, Downward ↓, Upward ↑
	02.19-07.19	54-75%	Inflation expectations	Downward ↓, Upward ↑
			Key policy rate	Downward ↓
			CPI	Upward ↑, Downward ↓
			Index of real wage	Upward ↑, Downward ↓, Upward ↑
	11.19	40%	Inflation expectations	Relatively low
			Key policy rate	Moderate
			CPI	On target
			Index of real wage	Relatively high

Source: author's calculations in E. VIEWS 10

Therefore, the applied technique makes it possible to identify periods of low, moderate or high volatility, as well as detailed characteristics of each of them. The downward or upward tendency of indicators included in the model partly explains what was the driving force of certain volatility. Besides that, the likelihood of being in regime may be related to current economic situation, for example if key policy rate and CPI are rising and index of real wage is declining, it presumably high volatility of inflation expectations take place.

CONCLUSION

The National Bank of Ukraine had changed the monetary policy regime due to the crisis and other economic circumstances, what brought inflation expectation channel of transmission mechanism in the focus of attention. Accordingly, the dynamic of inflation expectation, its volatility and interconnection with actions of the central bank became the topic of interest. The comprehensive review of the modeling tools reasonable for the case of investigation of inflation expectations, especially studies of Hamilton J. (1989), Nalewaik J. (2015), Simon J. (1996), Białowolski, P., Zwiernik, P., Żochowski, D. (2011) defined that autoregressive Markov switching model with several regimes might be the most appropriate econometric instrument for answering research questions.

In the view of goal of the research, applying the Markov model with three regimes the probabilities of low, moderate and high volatility of inflation expectations were determined. The lowest fluctuations of inflation expectation were possible only on 18-19% during all the research period, in the same time probabilities of moderate and high volatility are larger. Average volatility was probable on 40-80% in times of short runs of economic stabilization, while high fluctuation with probability of 66-99% were the most common phenomenon, because of crisis, structural changes, overall political and economic instability. Inflation expectations oscillated moderately in average for 5 months, simultaneously regimes with high and low volatility lasts in general for 1 and 4 months respectively. Furthermore, likelihood to switch from low fluctuations to high is equal to 99%, and it is possible to stay in this regime with probability of 74%, what also confirm the unstable situation in the country expressed in the considerable inflation expectations inconstancy.

Under the inflation targeting central bank can influence on prices and inflation expectations predominantly through the key policy rate as a main instrument of monetary policy. According to the developed Markov switching autoregression increase of the key policy rate on 1 percentage point in the low volatility regime lead to decrease of inflation expectations by 1.05%, whereas the regimes of moderate and high fluctuation characterized by increase of inflation expectations by 0,14% and 1,59% respectively.

Consequently, obtained results demonstrate significant influence of key policy rate, specifically within the regime of high volatility of inflation expectations, which is second in length referring to constant expected durations and the most probable on the estimated sample.

REFERENCES

Białowolski, P., Zwiernik, P., Żochowski, D. (2011), "Modelling Inflation Using Markov Switching Models: Case of Poland, 1992-2005", *SSRN Electronic Journal. Prace i Materiały*, Vol. 86, No. 1, pp. 185-199.

DelSole T. (2000), "A Fundamental Limitation of Markov models", *Journal of the Atmospheric Sciences*, Vol. 57, pp. 2158-2168.

Diebold, F., Lee, J-H., Weinbach, G. (1994), "Regime switching with time-varying transition probabilities", Oxford University Press, *Nonstationary Time Series Analysis and Cointegration.* (Advanced Texts in Econometrics, C.W.J. Granger and G. Mizon, eds.), pp. 283–303.

Hamilton, J. (1989), "A New Approach to the Economic Analysis of Nonstationary Time Series and the Business Cycle", *Econometrica*, Vol. 57, No. 2, pp. 357-384.

Hamilton, J. (1990), "Analysis of Time Series Subject to Changes in Regime", *Journal of Econometrics*, No. 45, pp. 39-70.

Holm-Hadula, F., Hubrich, K. (2017), "Macroeconomic implications of oil price fluctuations: a regime-switching framework for the euro area", *Working Paper Series. European Central Bank*..

Klaassen F. (2005), "Long Swings in Exchange Rates: Are They Really in the Data?", *Journal of Business & Economic Statistic*, Vol. 23, No. 1, pp. 87-95.

Koncherlakota, N. (2016), "Sluggish Inflation Expectations: A Markov Chain Analysis", *NBER Working Paper Series*.

Kuan, C-M. (2002), "Lecture on the Markov Switching Model", *Institute of Economics Academia Sinica*.

Lundbergh, S., Teräsvirta, T. (2000), "Forecasting with Smooth Transition Autoregressive Models", Clements M., Hendry D. (Ed.), *A Companion to Economic Forecasting*, Blackwell, UK, pp. 485-509.

Nalewaik, J. (2015), "Regime-Switching Models for Estimating Inflation Uncertainty", *Finance and Economics Discussion Series Divisions of Research & Statistics and Monetary Affairs Federal Reserve Board*.

Oliskevych M., Lukianenko, I. (2020), "European unemployment nonlinear dynamics over the business cycles: Markov switching approach", *Global Business and Economics Review*, Vol. 22, No. 4, pp. 375-401.

Pagliacci, C. Barráez, D. (2010), "A Markov-switching model of inflation: looking at the future during uncertain times." *Análisis Económico*, vol. XXV, № 59, pp. 25-46.

Runfang, Y., Jiangze, Du., Xiaotao, L. (2017), "Improved Forecast Ability of Oil Market Volatility Based on combined Markov Switching and GARCH-class Model", *Informational Technology and Quantitative Management*, No. 122, pp. 415-422.

Simon, J. (1996), "A Markov-Switching Model of Inflation in Australia", *Research Discussion Paper, Reserve bank of Australia*.

Teräsvirta, T. (2005), "Forecasting economic variables with nonlinear models", *SSE/EFI Working Paper Series in Economics and Finance*, No. 598.

Uzoma, U., Florence, A. (2016), "Application of Markov-Switching Regression Model on Economic Variables", *Journal of Statistical and Econometric Method*s, Vol. 5, No. 2, pp. 17-30.

Zhang, G., Patuwo, E., Hu, M. (1998), "Forecasting with artificial neural networks: The state of art", *International Journal of Forecasting*, No. 14, pp. 35-62.