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## **MULTIPLE STRUCTURAL BREAKS AND INFLATION PERSISTENCE IN BELARUS**

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# Multiple Structural Breaks and Inflation Persistence in Belarus

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## Abstract

This paper address the issue of assessing inflation persistence in Belarus using quarterly seasonally adjusted data over 1996–2011. To detect multiple structural breaks during the analyzed period, we applied recently developed and practically implemented in OxMetrics software impulse indicator saturation technique. Impulse indicator saturation break test allowed us to detect three structural breaks in dynamics of GDP deflator inflation and CPI inflation, including one at the end of the examined sample. All detected break dates have a clear-cut economic interpretation. Taking these structural brakes into account, while testing for dynamics properties of inflation and its persistence, we found that GDP deflator inflation and CPI inflation in Belarus are stationary variables with the changing means. Formal unit root testing with multiple structural breaks demonstrated that non-stationarity is rejected at one per cent significance level. The point estimates if inflation persistence for GDP deflator and CPI inflation are quite small (0.32 and 0.53 respectively). GDP deflator inflation and CPI inflation return to its equilibrium level after a shock in about 1.5 and 2 quarter correspondently. Thus, one can consider inflation persistence in Belarus over the sample period as a quite moderate. These results have the explicit policy implications. Low inflation persistence in Belarus is a sound prerequisite for macroeconomic stabilization and anti-inflation monetary policy. Additionally, the stationarity of inflation can be considered as an important element of the technical possibilities of implementing inflation targeting in Belarus.

*Keywords:* inflation persistence, univariate model, multiple structural brakes, means reversion, impulse indicator saturation, Autometrics.

*JEL Classification:* E31, C22, C51

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# 1 Introduction

In accordance with the definition, adopted by the Inflation Persistence Network (IPN)<sup>1</sup> for the euro area countries, inflation persistence is “the tendency of inflation to converge slowly towards its long-run value following a shock which has led inflation away from its long-run value” (Altissimo et al. (2006)). There are two main approaches to measure inflation persistence. The first one is usually based on the univariate autoregression models, where a shock to inflation comes from a residual term of autoregression, and the sum of the autoregressive coefficients for all included lags is considered as a scalar measure of inflation persistence. The second approach is based on the structural multivariate models, where the shocks come from the casual variables explaining inflation dynamics. In this paper we take an advantage of a univariate framework.

Measure of persistence is one of the key characteristics of inflation dynamics. An assessment of inflation persistence is essential for conduct of effective monetary policy, since the greater the degree of inflation persistence, the higher the costs of monetary policy in terms of reduction inflation. Various external and internal shocks hitting the economy will have a different impact on the inflation dynamics, according to degree of inflation persistence. Thus, the time horizon of monetary policy to stabilize inflation after such shocks will depend on the degree of inflation persistence. Apparently, less persistence inflation can be reduced in a shorter period of time and with smaller costs for the economy and population. On the contrary, more persistence inflation needs longer period for stabilization and the costs of disinflation will be considerably higher. In this context inflation persistence has become an important and topical issue in economic literature.

Among a number of the research questions concerning this topic, we would like to emphasize the following related issues that comprise the basis of our study:

- (1) Is inflation a stationary variable or unit root process?

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<sup>1</sup> In concordance with the ECB information, the Inflation Persistence Network (IPN) is a research team consisting of economists from the European Central Bank and the national central banks of the European Union conducting a coordinated research project on the patterns, determinants and implications of inflation persistence in the euro area and in its member countries.

- (2) Are there structural breaks (mean shifts) in the dynamics of inflation and how this affect its dynamics characteristics?
- (3) How to detect such structural breaks in the most appropriate way?
- (4) How to measure inflation persistence in a time series framework?
- (5) Is inflation is highly persistent or not, especially when the structural breaks are taken into account and what does it mean for anti-inflation monetary policy?

Despite the intensive research and a huge number of publications on inflation persistence, the issue remains controversial among economists. For instance, Pivetta and Reis (2007), analysing the US economy and using different measures and estimation procedures, argue that inflation persistence has been high, approximately unchanged over the examined sample, and the null hypothesis of a unit root for US inflation cannot be rejected. However, various studies within the IPN for the euro area countries pointed out that inflation in the euro area countries is moderately persistent or not persistent at all when structural break(s) in inflation dynamics is (are) taken into account<sup>2</sup>. In various studies empirical assessments of inflation persistence substantially diminish when statistically significant structural breaks (shifts in the mean of inflation) are accounted for; and contrariwise, ignoring the existence of structural breaks naturally leads to overrating inflation persistence (see, for instance, the following studies within the IPN: Corvoisier and Mojon (2005); (Bilke (2005); Marques (2004); Levin and Piger (2004)).

Although there is an extensive body of literature on the inflation persistence in the US, EU member states, and other countries, inflation persistence, however, has not yet been a subject of univariate econometric analysis in Belarus. Nevertheless, this country is an interesting case for studying inflation persistence using univariate approaches. Since 1995, the dynamics of inflation in Belarus is affected by various internal and external shocks, which, in turn, cause the structural breaks in the corresponding historical data. The deep currency crisis in 2011 led to the huge increase of inflation that reached a three-digit value. Currently, the reduction of inflation is one of the most vital problems for Belarusian economic authorities. In this context the understanding of inflation persistence in Belarus is of great importance for appropri-

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<sup>2</sup> For summary of current knowledge on inflation persistence and price stickiness in the euro area, based on research findings that have been produced in the context of the INP, see Altissimo et al. (2006).

ate monetary policy and macroeconomic stabilization measures. Additionally, the issue of inflation persistence is topical in the debates on the possibilities of inflation targeting in Belarus. In this paper we have attempted to fill the gap, using univariate framework for assessing inflation persistence in Belarus and taking into account the structural breaks in the dynamics of inflation.

As follows from Marques (2004), Marques and Dias (2010), any estimate of inflation persistence is conditional on the long run (equilibrium) level inflation. In the univariate framework this level can be approximated by the mean of inflation. Therefore, the ultimate estimates of inflation persistence will be highly sensitive to the determined mean level of inflation. Persistence will be the greatest, if one assumes a constant mean of inflation, and conversely, utilization of time varying mean will lead to the lower values of inflation persistence. The location of the equilibrium (long run) level of inflation as much important in the context of univariate analysis, that in compliance with Marques (2004), the “crucial dependence of the results on the assumed long run level of inflation obviously puts into question the usefulness of the univariate approach to investigate inflation persistence, unless we can find an acceptable proxy for the time varying mean of inflation”. In this connection, the abovementioned author concludes, that “before we are able to draw robust conclusions on inflation persistence, in the context of the univariate analysis, more work needs to be done in order to identify reliable measures for the long run level of inflation. A way out could be for researchers to agree on a small number of ways to compute a (potentially) time varying mean. This will allow obtaining comparable estimates for different countries and for different time periods”.

Thus, to measure the degree of inflation persistence properly, one has to identify the multiple structural breaks (possibly, multiple) in inflation dynamics, using appropriate econometrics techniques. Otherwise, one can get the erroneous conclusions about the degree of inflation persistence. Moreover, these conclusions will be dependent on the particular break testing method, since different techniques can give distinct break dates or even different number of breaks (Santos and Oliveira (2010)).

In empirical studies Bai-Perron sequential break test is one of the most frequently used procedure for detecting multiple structural breaks (Bai and Perron (1998); 2003)). This test has some limitations, especially in small samples and for the varia-

bles with high serial correlation. The need of trimming factor (minimum segment length) in the test reduces the number of observation available for date of structural breaks determination that, in turn, artificially reduces the number of potential breaks, particularly at the beginning and at the end of the sample (for further discussion see Castle et al. (2012); Santos and Oliveira (2010)).

In our research another break detection methods is used. In order to detect the number and the dates of possible structural breaks in inflation dynamics in Belarus, we employed recently developed impulse indicator saturation technique (Hendry et al. (2008); Johansen and Nielsen (2009); Hendry and Santos (2010)). Impulse indicator saturation technique enables to determine the structural breaks, outliers and possible data contaminations, and provides a general procedure for analyzing constancy of the models. Impulse indicator saturation is a generic test for an unknown number of breaks, occurring at unknown times, with unknown duration and magnitude, anywhere in the sample. Additionally, many existing procedures can be interpreted as special cases of impulse indicator saturation, including the Bai and Perron (1998; 2003) multiple breakpoint test mentioned above (Ericsson (2011)).

In Castle et al (2012) model selection procedure based on general-to-specific approach and impulse indicator saturation, when there are multiple breaks are considered. The authors, using intensive Monte Carlo simulation convectively demonstrate that impulse indicator saturation technique in conjunction with *Autometrics* routine succeeded to detect up to 20 shifts in 100 observations. Using empirical example of the US *ex-post* real interest rate from Bai and Perron (1998), they showed that impulse indicator saturation technique found a similar number and timing of breaks over initial sample period as the Bai-Perron multiple breakpoint test. However, when the sample period was substantially extended, impulse indicator saturation revealed substantial benefits, detecting the breaks and outliers near the start and end of the sample as well as other shifts.

The first implementation of impulse saturation breaks test (Santos (2008)) for assessment of inflation persistence is presented in Santos and Oliveira (2010). Detecting structural breaks having used the saturation breaks test, the authors then built congruent autoregressive model of inflation. On the basis of this autoregression model with structural breaks accounted for, they concluded against inflation persistence in

France and unit root hypothesis over the sample period. In this study the authors also found that impulse indicator saturation performs better in small samples with high serial correlation than Bai-Perron sequential multiple breakpoint test.

The papers mentioned above formed the basis of our examination of inflation persistence in Belarus under multiple structural breaks. We also utilized several approaches for measuring of inflation persistence within univariate framework that intensively discusses in Marques (2004), Marques and Dias (2010). In Pelipas (2011), we addresses the issue of determining the order of integration of inflation and growth rates of monetary aggregates in Belarus under multiple structural breaks and proposes the modified unit root test, where, on the first stage, the structural breaks are determined endogenously by impulse indicator saturation technique, and then the matching break points are utilized exogenously in the appropriate Dickey-Fuller unit root test. Such an approach allows unit root testing for any number of structural breaks. This paper is a logical extension of the former study and implementation impulse indicator saturation techniques for analysis of inflation persistence in Belarus.

The structure of the rest of the paper is as follows. In section 2 the various definitions of inflation persistence are briefly discussed; then the measures of inflation persistence used in our empirical analysis are considered. Section 3 reports empirical results of inflation persistence examination in Belarus over 1995–2011; we detect first multiple structural breaks in inflation dynamics using indicator saturation break test and then testing analyzed variables for unit root and examine degree of inflation persistence taken found structural breaks into account. Section 4 concludes.

## **2 Inflation Persistence: Definition and Measures**

### **2.1 Definition of inflation persistence**

There are several definitions of inflation persistence available in the literature. Let's consider some of them that obviously have a common essence. For instance, Willis (2003) defines persistence as the “speed with which inflation returns to baseline after a shock”. Marques (2004) slightly modified this definition introducing concept of equilibrium: inflation persistence is the “speed with which inflation converges to equilibrium after a shock”. The IPN defines inflation persistence, as “the tendency of inflation

to converge slowly towards its long-run value following a shock which has led inflation away from its long-run value” (Altissimo et al. (2006)).

All abovementioned definitions imply that any measure of inflation persistence is conditional on long-run or equilibrium inflation level. Thus, any estimations of inflation persistence will depend on the determined equilibrium level of inflation. Apparently, if one assumes the constant long-run level of inflation, while this level actually is time varying, as a result we will obtain erroneous conclusions concerning the degree of inflation persistence. By this means, reliability of univariate methods of inflation persistence analysis strongly depends on estimated (or assumed in the case of inflation targeting) equilibrium level of inflation (for more detailed discussion see Marques (2004)).

Concluding this sub-section, it should be noted that there are two key issues for empirical analysis following from the given definition of inflation persistence: the first one is an equilibrium inflation level that a researcher has to estimate econometrically, and the second one is the a speed of adjustment of inflation after a shock, that can be considered using concept of integration/cointegration and equilibrium correcting framework.

## 2.2 Measures of inflation persistence

Considering various measures of inflation persistence presented in economic literature, we relied on Marques (2004). Usually, in the framework of the univariate autoregressive model the sum of autoregressive coefficients for all lags included in the autoregression is considered as a scalar measure of inflation persistence<sup>3</sup>.

Let us assume that a natural logarithm of inflation,  $\pi_t = cpi_t - cpi_{t-1}$ , where  $cpi_t$  is a log of consumer price index (or another appropriate price index), and  $p$  is a number of lags. Then a standard autoregression that is usually applied in assessing inflation persistence may be written as

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<sup>3</sup> In Marques and Dias (2010) a new measure for persistence is proposed. This measure of persistence is defined as the unconditional probability of a stationary stochastic process not crossing its mean in the time period  $t$ . It has the important property of being model free. Thus, to use this measure of inflation persistence, one does not need to specify and estimate the model of inflation.



$$\pi_t = \beta_0 + \sum_{i=1}^p \beta_i \pi_{t-i} + \epsilon_t, \quad \epsilon_t \sim iid(0, \sigma^2). \quad (1)$$

The process, represented by autoregression (1), allows for changes in the level of inflation as the intercept term  $\beta_0$  is time varying; changes in the unconditional mean of inflation,  $\mu_t = \beta_0 / (1 - \sum_{i=1}^p \beta_i)$ ; and changes in the persistence of inflation, measured by the sum of autoregressive coefficients for all lags included in (1),  $\alpha = \sum_{i=1}^p \beta_i$ . The unconditional mean,  $\mu$  can change because of changes in the intercept,  $\beta_0$  or in the persistence parameter,  $\alpha$ , or when both  $\beta_0$  and  $\alpha$  are changed. In the model (1), when the level of inflation changes, one has to distinguish if inflation should be modeled as stochastic process with a unit root and  $\alpha = 1$ , or as deterministic process with  $|\alpha| < 1$  but in the presence of the structural break(s).

The autoregression model (1) can be reparameterised and presented in the form of well-known augmented Ducky-Fuller unit root test:

$$\Delta\pi_t = \beta_0 + (\rho - 1)\pi_{t-1} + \sum_{i=1}^{p-1} \delta_i \Delta\pi_{t-i} + \epsilon_t, \quad \epsilon_t \sim iid(0, \sigma^2), \quad (2)$$

where  $\rho = \alpha = \sum_{i=1}^p \beta_i$  and  $\delta_i = -\sum_{j=1+i}^p \beta_j$ . In the model (2) inflation persistence is defined as the speed with which inflation returns to its long-run (equilibrium) level after a shock in disturbance term,  $\epsilon_t$ , that raises inflation at the moment  $t$  by one unit or standard deviation.

In Pelipas (2011) it is argued that augmented Dickey-Fuller unit root test is intrinsically a univariate case of the vector autoregression model with equilibrium correction mechanism. If inflation in (1) is a stationary variable, then it is cointegrated with itself, and a coefficient  $(\rho - 1)$  in (2) will take the following values:  $-1 \leq (\rho - 1) < 0$ . This means that any departure of inflation from its equilibrium level after a shock will be corrected. In fact, this is similar to the feedback coefficients in Johansen's multivariate cointegration model that characterize the speed of the equilibrium correction in the system. In this context, it is possible to reformulate Dickey-Fuller unit root test, treating the multiply changes of the mean as in the vector autoregression model with equilibrium correction mechanism in the case when a constant are restricted in cointegration space:

$$\Delta\pi_t = [\beta_0 + (\rho - 1)\pi_{t-1} + \sum_{j=1}^k \varphi_j SD_{j,t-1}] + \sum_{i=1}^{p-1} \delta_i \Delta\pi_{t-i} + \sum_{j=1}^k \sum_{i=0}^{p-1} \gamma_{ij} \Delta SD_{ij,t-i} + \epsilon_t, \quad (3)$$

where  $k$  is number of structural breaks (step dummies characterizing changes in the mean of inflation);  $p$  is a number of lags in the regression;  $SD_{i,t} = 1(t \geq Tb_i + 1)$ ;  $Tb_j$  is the point of the  $j$ -th structural break;  $\Delta SD_{i,t} = SD_{i,t} - SD_{i,t-1}$ ;  $\beta_0, \rho - 1, \varphi_j, \gamma_{ij}, \delta_i$  are the parameters of the regression, and  $\epsilon_t$  is an error term.

The brackets in (3) mark the “long-term” component of inflation dynamics. This component is composed of the constant, characterizing the mean of the variable, the step dummies, reflecting the changes in the mean and taken as in Johansen cointegration procedure with one lag, and inflation itself with one lag. By analogy with Johansen cointegration approach “short-term” part of model (3) includes the lags of dependent variable and lags of the first difference of step dummies. Thus, we have the equilibrium correction model but for only one variable with the set of deterministic terms (constant and step dummies). The coefficient  $(\rho - 1)$  one can treat as an equilibrium correction mechanism and its significance can be tested using critical values from the cointegration test for conditional equilibrium correction model (see Ericsson and MacKinnon (2002)). The step dummies in model (3) can be considered as the additional variables in cointegration vector and then one can use the critical values in accordance with the total number of such variables. If the break points are determined, proposed approach permits unit root testing for any number of structural breaks.

The concept of inflation persistence is closely related to the impulse response function of the autoregressive process. The sum of the autoregressive coefficients in (1) is positively related to the cumulative impulse response function (Andrews and Chen (1994); Marques (2004)). Additionally, if  $\alpha \in [-1, 1]$ , the cumulative effect of one-time shock in disturbance term  $\varepsilon_t$  on inflation can be represented as cumulative impulse response:

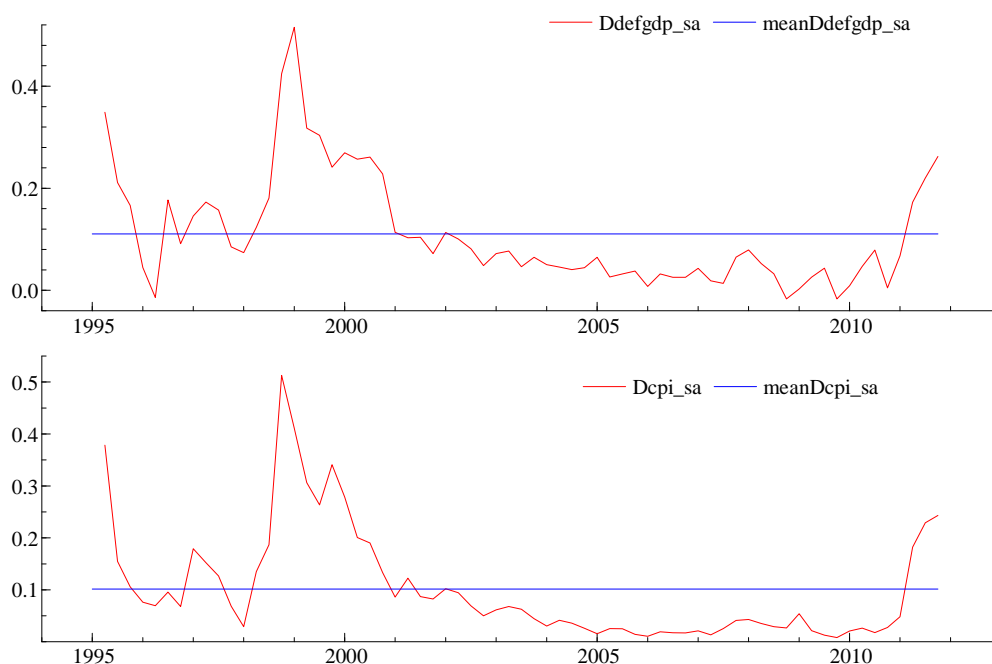
$$CIR = \sum_{j=0}^{\infty} \frac{\partial \pi_{t+j}}{\partial \varepsilon_t} = \frac{1}{1 - \alpha}. \quad (4)$$

In accordance with (4), if inflation series is a unit root process, cumulative impulse response function will never die out, however, it dies when inflation is stationary. Consequently,  $CIR$  also can be used as a measure of inflation persistence: when the

autoregressive processes with  $\alpha$  close to 1 will be more persistent than the process with  $\alpha$  close to 0.

### 3 Empirical Results

In this section we analyze inflation persistence in Belarus for over the period 1995–2011 (68 observations). Quarterly data on GDP deflator and Consumer Price Index (CPI) are used for assessments of inflation persistence. Since these time series had a significant seasonal pattern, they have been seasonally adjusted using ARIMA X-12 method. Then the data have been transformed into natural logarithms and the first differences are taken to obtain an approximation of GDP deflator inflation (**Ddefgdp\_sa**) and CPI inflation (**Dcpi\_sa**). The data used in further analysis (with constant means) are presented in Figure 1. As one can see, GDP deflator inflation and CPI inflation demonstrated intricate dynamics with possible structural breaks and regimes changes. Simple Dickey-Fuller unit root test with constant does not reject the null hypothesis for **Ddefgdp\_sa** at 5% significance level ( $p = 0.057$ ), but reject the null for **Dcpi\_sa** ( $p = 0.031$ ). These results, however, are very sensitive to sample period: if the sample would be shifted just one quarter ahead, then the unit root null hypothesis will not be rejected for **Dcpi\_sa** (for more details see Pelipas (2011)).



**Figure 1: Dynamics of GDP deflator inflation and CPI inflation in Belarus**

### 3.1 Determining the structural breaks in inflation dynamics

Since 1995, the dynamics of inflation in Belarus is affected by various internal and external shocks, which in turn cause the structural breaks in the corresponding time series. Such structural breaks should be properly detected and taken into account while assessing inflation persistence. In order to detect the number and the dates of possible structural breaks in inflation dynamics in Belarus, we employed recently developed method of impulse indicator saturation (Hendry et al. (2008); Johansen and Nielsen (2009); Hendry and Santos (2010)).

To analyze the properties of econometric model, this method uses zero-one impulse indicator dummies. Since there are potentially  $T$  such dummy variables, inclusion all of them in a model is infeasible. However, the impulse indicator dummies can be included in a model as the separate blocks. In the simplest case with two blocks, the sample is split on two equal parts ( $T/2$ ), then the impulse indicator dummies are included only for the first half of the sample, and statistically significant dummies at a chosen significant level are stored. Further, chosen at the previous step the impulse indicator dummies are dropped, and then another part of the dummies are included in the model. After that, procedure is repeated for the second part of the sample. Statistically significant impulse indicator dummies from two blocks are combined, and jointly significant ones are retained. A computational algorithm, utilized in recent version of OxMetrics (*Autometrics* routine) software, performs optimal splitting for any number of blocks selecting the final model.

Thereafter we employ impulse indicator saturation technique to detect the structural breaks and its points in dynamics of inflation  $\pi_t$ , using a location shift model that includes only constant and impulse indicators for every observation:

$$\pi_t = \mu + \sum_{s=1}^T \delta_s I_{s,t} + \epsilon_t, \quad \epsilon_t \sim iid(0, \sigma^2), \quad t = 1, \dots, T, \quad (5)$$

where  $I_{s,t} = 1$  for period  $s$ , and 0 otherwise. Thus, in the model (5) there are more variables than observations. *Autometrics* algorithm allows to get the final model from such kind of general unrestricted model using optimal splitting for any number of blocks of the variables.

We applied indicator saturation break test to identify breaks in dynamics of GDP deflator inflation and CPI inflation in Belarus, using the model (5) with non-fixed constant and 1% significance target level. Eventually, only significant coefficients retained in the regressions. The regression results for **Ddefgdp\_sa** and **Dcpi\_sa** are presented below.

Ddefgdp_sa					Dcpi_sa				
	Coefficient	Std.Error	t-value	t-prob		Coefficient	Std.Error	t-value	t-prob
Constant	0.0536821	0.004912	10.9	0.0000	Constant	0.0563221	0.005127	11.0	0.0000
I:1995(2)	0.295104	0.03332	8.86	0.0000	I:1995(2)	0.321908	0.03202	10.1	0.0000
I:1995(3)	0.157462	0.03332	4.73	0.0000	I:1995(3)	0.0985483	0.03202	3.08	0.0039
I:1995(4)	0.112587	0.03332	3.38	0.0015	I:1997(1)	0.122874	0.03202	3.84	0.0005
I:1996(3)	0.123231	0.03332	3.70	0.0006	I:1997(2)	0.0959224	0.03202	3.00	0.0049
I:1997(1)	0.0918339	0.03332	2.76	0.0085	I:1998(2)	0.0789465	0.03202	2.47	0.0184
I:1997(2)	0.119331	0.03332	3.58	0.0008	I:1998(3)	0.130612	0.03202	4.08	0.0002
I:1997(3)	0.103655	0.03332	3.11	0.0033	I:1998(4)	0.456405	0.03202	14.3	0.0000
I:1998(3)	0.127128	0.03332	3.82	0.0004	I:1999(1)	0.354601	0.03202	11.1	0.0000
I:1998(4)	0.370774	0.03332	11.1	0.0000	I:1999(2)	0.249872	0.03202	7.80	0.0000
I:1999(1)	0.461528	0.03332	13.9	0.0000	I:1999(3)	0.207266	0.03202	6.47	0.0000
I:1999(2)	0.263955	0.03332	7.92	0.0000	I:1999(4)	0.284446	0.03202	8.88	0.0000
I:1999(3)	0.250175	0.03332	7.51	0.0000	I:2000(1)	0.222162	0.03202	6.94	0.0000
I:1999(4)	0.187617	0.03332	5.63	0.0000	I:2000(2)	0.144342	0.03202	4.51	0.0001
I:2000(1)	0.215971	0.03332	6.48	0.0000	I:2000(3)	0.133992	0.03202	4.19	0.0002
I:2000(2)	0.203220	0.03332	6.10	0.0000	I:2001(2)	0.0661181	0.03202	2.07	0.0460
I:2000(3)	0.207278	0.03332	6.22	0.0000	I:2005(1)	-0.0408245	0.03202	-1.28	0.2102
I:2000(4)	0.174403	0.03332	5.23	0.0000	I:2005(3)	-0.0311855	0.03202	-0.974	0.3364
I:2008(4)	-0.0706015	0.03332	-2.12	0.0398	I:2005(4)	-0.0419994	0.03202	-1.31	0.1977
I:2009(4)	-0.0706473	0.03332	-2.12	0.0396	I:2006(1)	-0.0457600	0.03202	-1.43	0.1613
I:2011(2)	0.118878	0.03332	3.57	0.0009	I:2006(2)	-0.0369744	0.03202	-1.15	0.2556
I:2011(3)	0.166294	0.03332	4.99	0.0000	I:2006(4)	-0.0392492	0.03202	-1.23	0.2280
I:2011(4)	0.208719	0.03332	6.26	0.0000	I:2007(2)	-0.0429134	0.03202	-1.34	0.1883
					I:2008(4)	-0.0297160	0.03202	-0.928	0.3594
					I:2009(2)	-0.0348666	0.03202	-1.09	0.2832
					I:2009(3)	-0.0435872	0.03202	-1.36	0.1816
					I:2010(3)	-0.0387300	0.03202	-1.21	0.2341
					I:2011(2)	0.126079	0.03202	3.94	0.0003
					I:2011(3)	0.172897	0.03202	5.40	0.0000
					I:2011(4)	0.186902	0.03202	5.84	0.0000

**Table 1: The dates of structural breaks of inflation dynamics in Belarus**

Variable	The dates of the structural breaks (year and quarter)	Number of the different regimes
GDP deflator Inflation (Ddefgdp_sa)	1998q2; 2000q4; 2011q1	4
CPI inflation (Dcpi_sa)	1998q2; 2000q3; 2011q1	4

*Source:* Author' calculations.

We consider the structural break as continuous sequence of statistically significant indicator variables with the same signs and approximately the same magnitudes (continues sequence equal to 6 quarters are chosen arbitrary for practical reasons; additionally, we consider sequence of only 3 quarters at the end of the sample also as a structural break; these segments are shadowed in the results presented above). All other statistically significant indicator variables are treated as outliers. In accordance

with the results indicator saturation break test, that GDP deflator and CPI inflation in Belarus have the structural breaks over a period of 1995-2011. All in all, three structural breaks and four different regimes were detected in the dynamics of GDP deflator and CPI inflation. The specific dates of the structural breaks that have been obtained by impulse indicator saturation break test are presented in Table 1.

Impulse indicators determined by indicator saturation break test are grouped into three step dummies, characterizing the structural breaks and duration of different regimes in inflation dynamics. For **Ddefgdp\_sa** these step dummies are **dumm1998q3**, **dumm2001q1** and **dumm2011q2**, respectively; and similarly for **Dcpi\_sa** variable: **dumm1998q3**, **dumm2000q4** and **dumm2011q2**. Using location shift model with these step dummies gives the following results:

EQ(1) Modelling Ddefgdp\_sa by OLS  
The estimation sample is: 1995(2)-2011(4)

	Coefficient	Std.Error	t-value	t-prob
Constant	0.137177	0.01684	8.14	0.0000
dumm1998q3	0.162710	0.02554	6.37	0.0000
dumm2001q1	-0.251656	0.02142	-11.70	0.0000
dumm2011q2	0.170081	0.03632	4.68	0.0000

EQ(2) Modelling Dcpi\_sa by OLS  
The estimation sample is: 1995(2)-2011(4)

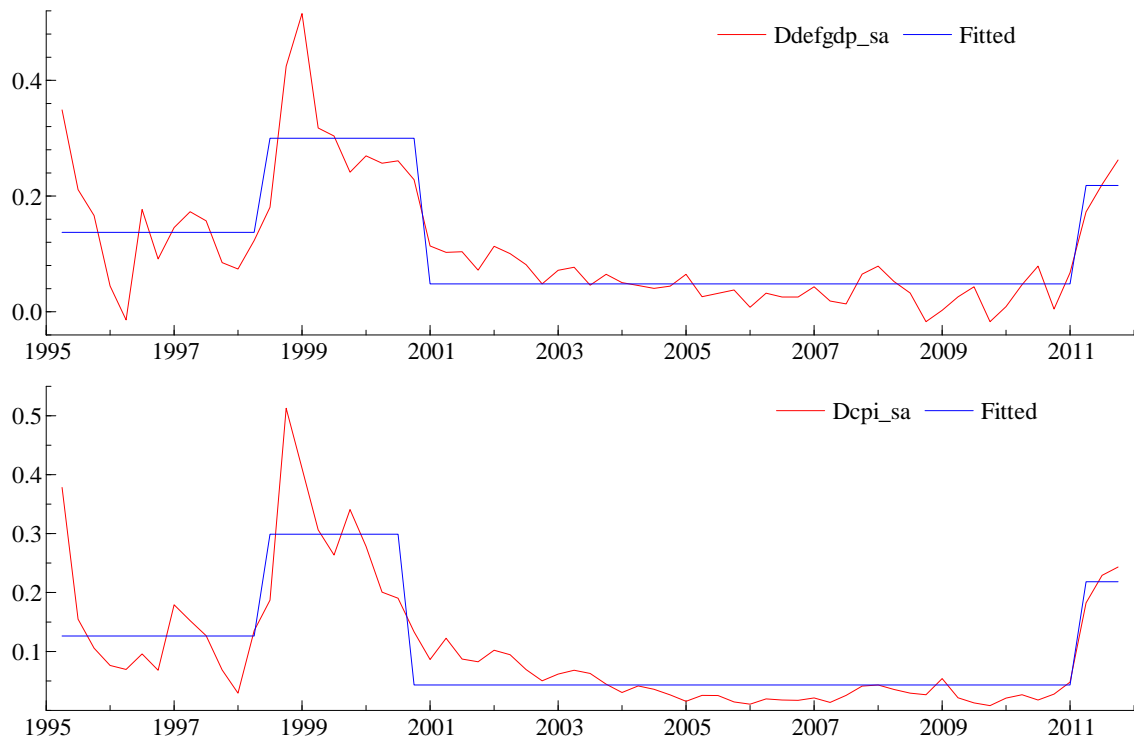
	Coefficient	Std.Error	t-value	t-prob
Constant	0.126142	0.01673	7.54	0.0000
dumm1998q3	0.172813	0.02615	6.61	0.0000
dumm2000q4	-0.255708	0.02215	-11.50	0.0000
dumm2011q2	0.175035	0.03604	4.86	0.0000

For visualization, the obtained results are presented in graphical form in Figure 2.

The results of structural break test based on impulse indicator saturation are clearly consistent with real dynamics of GDP deflator and CPI inflation, and the break points have an explicit economic interpretation. Specifically, the structural break in 1998q2 is caused by the Russian financial crisis in August 1998. The structural break in 2000q3-4 occurs due to adoption of unified exchange rate for Belarusian ruble and the following changes of monetary policy. Finally, the structural break in the first quarter of 2011 is related to the deep currency crisis and the consequent huge devaluation of Belarusian ruble.

Since all break points have a clear-cut economic interpretation, the inclusion of the appropriate dummies, taking into account the impact of such breaks in a unit

root test, using for assessment of inflation persistence, is not just a “fitting” of the regression; it is based on a solid economic ground. It is also important, that the break points are chosen endogenously within impulse indicator saturation break test and they reflect real peculiarities of inflation dynamics in Belarus.



Source: Author' calculations.

**Figure 2: Structural breaks in dynamics of inflation in Belarus**

It is interesting to note, that widely used Bai-Perron multiple break test (Bai and Perron (1998); (2003)) in our case is not able to determine the third structural break at the end of the sample correctly (see explanations of this in Castle et al. (2012); Santos and Oliveira (2010)).

### 3.2 Assessing inflation persistence

To analyze inflation persistence in Belarus over the period of 1995q1-2011q4, we start with unit root testing of `Ddefgdp_sa` and `Dcpi_sa`, taken into account multiple structural breaks determined by indicator saturation break test and using model (3). The essence of this approach is as follows.

(1) The break points in the dynamics of GDP deflator and CPI inflation are determined endogenously using multiple structural breaks test based on impulse indicator saturation.

(2) On the basis of the impulse indicator saturation break test, the step dummies are created; these step dummies characterize different regimes in dynamics of GDP deflator and CPI inflation and reflect the changes in variables mean.

(3) The step dummies, created on the previous stage, are included in the univariate Dickey-Fuller unit root test by analogy with dummy variables included in cointegrated vector in the Johansen (1988) multivariate cointegration test.

(4) Testing for null hypothesis of unit root,  $t$ -statistics in Dickey-Fuller test ( $t$ -ADF) are compared with critical values calculated for cointegration test in the conditional equilibrium correction model framework (see Ericsson and MacKinnon (2002)).

The regressions for **Ddefgdp\_sa** and **Dcpi\_sa** based equation (3) are presented below.

EQ(3) Modelling DDdefgdp\_sa by OLS  
The estimation sample is: 1995(3)-2011(4)

	Coefficient	Std.Error	t-value	t-prob
Constant	0.074324	0.01997	3.72	0.0004
Ddefgdp_sa_1	-0.673122	0.10280	-6.55	0.0000
dumm1998q3_1	0.138159	0.02760	5.01	0.0000
dumm2001q1_1	-0.181498	0.03218	-5.64	0.0000
dumm2011q2_1	0.146047	0.03835	3.81	0.0003
Ddumm1998q3	0.066199	0.05056	1.31	0.1956
Ddumm2001q1	-0.173318	0.05183	-3.34	0.0015
Ddumm2011q2	0.119512	0.04920	2.43	0.0182

AR 1-5 test:  $F(5,53) = 1.0312$  [0.4089]

EQ(4) Modelling DDcpi\_sa by OLS  
The estimation sample is: 1995(4)-2011(4)

	Coefficient	Std.Error	t-value	t-prob
DDcpi_sa_1	0.0786815	0.07053	1.12	0.2696
Constant	0.0491942	0.01413	3.48	0.0010
Dcpi_sa_1	-0.4734570	0.09596	-4.93	0.0000
dumm1998q3_1	0.0610597	0.02525	2.42	0.0191
dumm2000q4_1	-0.0916489	0.03013	-3.04	0.0037
dumm2011q2_1	0.1002410	0.03405	2.94	0.0048
Ddumm1998q3	0.0581723	0.03180	1.83	0.0729
Ddumm1998q3_1	0.2999790	0.03500	8.57	0.0000
Ddumm2000q4	-0.0762453	0.03391	-2.25	0.0287
Ddumm2000q4_1	0.0019129	0.03167	0.06	0.9521
Ddumm2011q2	0.1368310	0.02967	4.61	0.0000
Ddumm2011q2_1	0.0037677	0.04239	0.09	0.9295

AR 1-5 test:  $F(5,48) = 1.4364$  [0.2284]



The lag structure of the abovementioned models is chosen so to eliminate residual autocorrelation in (3). For **Ddefgdp\_sa** the specification with zero lag was sufficient to eliminate autocorrelation; for **Dcpi\_sa** one lag is needed (AR 1-5 test for serial correlation is insignificant for both regressions). The coefficients at the step dummies, characterizing changes in the mean, are statistically significant. Their signs correctly indicate the directions of the regimes changes in dynamics of the variables.

Table 2 reports the results of unit root tests for GDP deflator inflation and CPI inflation. According to  $t$ -ADF the null hypothesis of unit root is rejected at 1 per cent significance level for all examined variables. Therefore, GDP deflator and CPI inflation are stationary variables with the changing means. This fact rules out inflation persistence in Belarus over the sample period. It should be added that point estimates of inflation persistence for GDP deflator and CPI inflation are quite small (0.32 and 0.53 correspondently). As it follows from table 2, GDP deflator inflation returns to its equilibrium level after a shock in about 1.5 quarter; for CPI inflation this value is about 2 quarters.

**Table 2: Unit root test with three structural breaks and inflation persistence measures**

Variable	$t$ -ADF (n)	$\rho - 1$	Persistence measures	
			$\rho$	$1/1 - \rho$
GDP deflator inflation ( <b>Ddefgdp_sa</b> )	-6.55 (0)**	-0.673	0.327	1.49
CPI inflation ( <b>Dcpi_sa</b> )	-4.93(1)**	-0.473	0.527	1.90

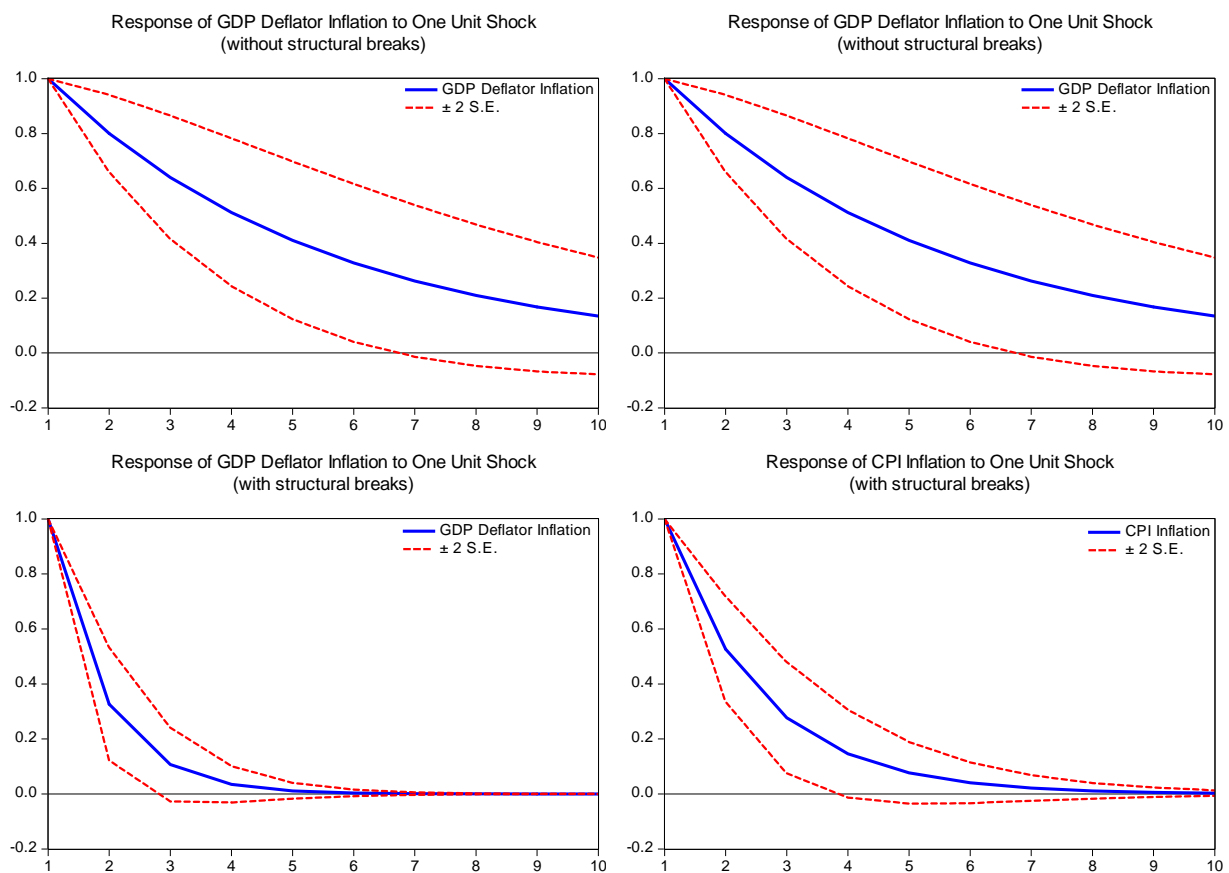
*Source:* Author' calculations.

*Notes:* \*\* denote rejection of null hypothesis at the one per cent significance level.  $t$ -ADF(n) is  $t$ -statistic in ADF-test for unit root with changing mean; n is the lag length chosen so to eliminate residual autocorrelation in (3). Critical values are determined on the basis of Ericsson and MacKinnon (2002).

Additionally, we can consider inflation persistence in terms of impulse response functions, based on the unit root test with multiple structural breaks (figure 3). The upper panel of figure 2 represents response of GDP deflator inflation and CPI inflation to one unit shock (with appropriate confidence bands) without taking into account multiple structural breaks in the dynamics of the inflation variables. In such

case it takes about 7 quarters to return GDP inflation and CPI inflation to an equilibrium level after a shock. Thus, inflation in Belarus without taken into account structural breaks can be erroneously classified as persistent process.

It is also important to note that the results of ADF-test for of GDP deflator inflation and CPI inflation without structural breaks are very sensitive to sample period and lag length. The null of unit root is rejected for these variables only for the whole sample and when optimal lag length chosen by the different information criteria. However, if the lag length would be chosen so to remove autocorrelation of the residuals and, at the same time, the sample would be shifted barely two or three quarters ahead, then the unit root null hypothesis would not be rejected for both examined variables. Hence, the usage of unit root test without structural breaks in our case does not provide the reliable and noncontradictory results.



Source: Author's calculation.

**Figure 3: Response of inflation to one unit shock in Belarus**

On the contrary, the impulse response functions, presented on the lower panel of figure 3, are in line with the results from table 2. When multiple structural breaks are taken into account, then impulse responses are “well-behaved”. In such case, it takes about 1.5 and 2.5 quarters respectively to return GDP deflator inflation and CPI inflation to its equilibrium level after a shock. Therefore, impulse response analysis also rules out inflation persistence in Belarus.

## 4 Conclusion

The assessments of inflation persistence in Belarus on the basis of quarterly seasonally adjusted data for 1995-2011, using a univariate framework have and taken into account the structural breaks in dynamic of inflation, have led to the following results that allow us to answer the main research questions raised in this paper.

As a result of impulse indicator saturation break test, three structural breaks were detected in the dynamics of GDP deflator inflation and CPI inflation. All break points have a clear-cut economic interpretation. The first structural break in 1998Q3 is caused by the financial crisis in Russia in August 1998. The second break has occurred in 2000Q4-2001Q1 due to adoption of unified exchange rate for Belarusian ruble and the following changes of monetary policy. The third structural break in the second quarter of 2011 is related to the deep currency crisis and the consequent huge devaluation of Belarusian ruble.

When these structural breaks are taken into account, GDP deflator inflation and CPI inflation in Belarus are stationary variables with the changing means. Formal unit root testing demonstrated that non-stationarity is rejected at one per cent significant level. Thus, persistence GDP deflator inflation and CPI inflation is ruled out. At most, one can consider inflation persistence in Belarus over the period of 1995-2011 as a very moderate. The point estimates of inflation persistence for GDP deflator and CPI inflation are quite small (0.32 and 0.53 respectively). GDP deflator inflation and for CPI inflation return to its equilibrium level after a shock in about 1.5 and 2 quarter correspondently.

The results of the point estimates of inflation persistence confirm by the impulse response analysis. When multiple structural breaks are taken into account, it takes about 1.5 and 2.5 quarters respectively to return GDP deflator inflation and CPI in-

flation to its equilibrium level after a one unit shock. Thus, impulse response analysis also rules out inflation persistence in Belarus.

The results presented above have the explicit policy implications. Low inflation persistence in Belarus is a sound prerequisite for macroeconomic stabilization and anti-inflation monetary policy. In any case, adequate monetary policy will lead to substantial reduction of inflation in the future. Additionally, the stationarity of inflation can be considered as an important element of the technical possibilities of implementing inflation targeting in Belarus.

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