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Labor Force Participation in Eastern European Countries: Nonlinear Modeling

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Labor Force Participation in Eastern European Countries: Nonlinear Modeling

Abstract:

Purpose

The purpose of this paper is to investigate the behavior peculiarities of the labor force participation in Eastern European countries.

Design/methodology/approach

The authors provide the analysis of nonlinearity in dynamics of economic active population and perform the econometric analysis using logistic smooth transition autoregressive models that are flexible and capture various kinds of behavior for different modes. The paper investigates labor markets of six Eastern European countries, Hungary, Bulgaria, Poland, Slovakia, Romania and Croatia, that are characterized by lower lever of labor force participation rate than average level in EU.

Findings

The results of modeling quantitatively characterize smooth changes in the behavior modes of labor force activity for each country and indicate how population economic activity depend on previous labor market states. The estimated slope parameters that determine the smoothness of transition between regimes show that, in all countries, the labor force participation quite quickly reacts to changes that occurred on the labor market in the past. During recession periods, households of European countries that joint EU last decade in order to prevent the depletion of their total income increased labor supply and showed increased activity in job search.

Originality/value

This paper indicate the nonlinearity and asymmetry in labor force participation rate in transition economies, discovers variety of its dynamics in the different regimes and determines the indicators that cause the change of the population economic activity behavior in each country.

Keywords: Labor force participation; Nonlinearity; Smooth transition model, Labor market, Eastern Europe.

JEL Classification: C 30, E 24

1. Introduction and Literature Review

The activity of population on labor markets in European countries has been demonstrated a positive tendency over last decades. The labor force participation has been increased by near ten percentages since 1998 almost in all countries. However, we observed significantly different level of desirability and alacrity to work in different countries. Thus, in Switzerland, Sweden, Finland, Netherland, Austria, Germany, the economic activity of population was high and continue to increase whereas, in Hungary, Poland, Slovakia, Bulgaria, Croatia, Greece, it was below the average EU level and showed declining dynamics in some periods (Fig. 1). Different countries exhibited also different seasonal pattern and business cycle fluctuations. Besides this, strong negative disturbances in economics that took place in 2008–2009 caused different negative impacts on economic activity of population in searching job because of unfavorable expectations but these effects were not inherent for all the regions. Some countries demonstrated rising of labor force participation rate even during recession.

The economic activity of population that aimed to participate in labor force depends on many factors. Moreover, the changes in these factors lead to distinctive consequences for the labor market indicators in different countries. The labor market reactions are caused by specific of the region and show strong polarization, especially in the post-crisis periods (Beyer and Stemmer, 2016). In the long run, the demographic distribution (Otoiu, 2017), education system development (Jez, 2015; Amaral, Queiroz and Calazans, 2015), population age structure (Batyra et al, 2016; Anghelache et al, 2016), social norm preferences to work (Zweig, 2015; Balleer et al, 2014) are the important factors influencing the labor market. The deviation in aggregate labor force participant

for different countries is partly the result of differences in the labor participation of women that is considerably distinctive for developed countries (Brenke, 2015; Johnson, 2014; Mishra and Smyth, 2010) and developing countries (Husain, 2016; Hare, 2016; Tam, 2011). A broad spectrum of social standard (Koursaros, 2017), properties of economic growth, peculiarities of international migration (Prat, 2016; Nica, 2015; Christofides et al, 2007) and historical conditions (Bozani and Drydakis, 2015; Gaddis and Klasen, 2014) are other important factors of labor market development in the long-run.

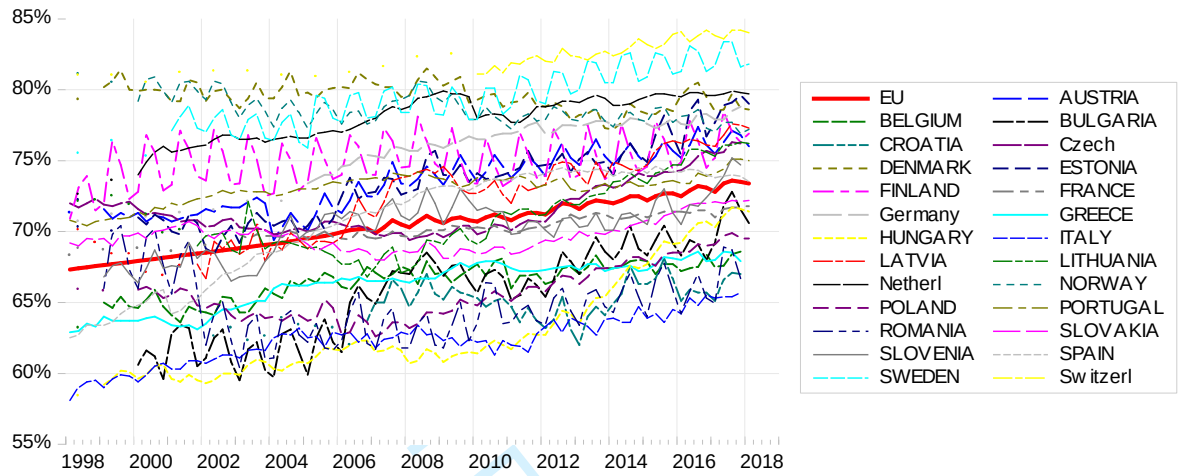


Fig. 1. Dynamics of population economic activity on labor markets of European countries during 1998–2017

Source: EUROSTAT Database, authors' elaborations.

The long-term tendencies describe only part of dynamic properties of the labor market indicators. Cyclical factors that are caused by business cycle and fluctuations of general economic activity are even more substantive (Lucian, 2017; Zandweghe, 2012). Nucci and Riggi (2018) suggest that economic activity on European labor market is countercyclical and labor force participation rate can relate to unemployment rate during recession. However, the scientists emphasize that despite of existed correlation between cyclical unemployment and economic activity of population directed to job searching (Elsby et al, 2013; Feng et al, 2017; .Petrongolo and Pissarides, 2008), the correlation sign and causality of such a relation are various for different countries and depend on the economic environment. Yuldashev and Khakimov (2011), Senaj et al. (2016) found that in some European countries the labor force participation is sensitive to changes in wages, income taxes and transfers albeit the elasticity is small.

Furthermore, scientists suggest that, in addition to demographic circumstances and cyclical factors, such factors as educational level (Orbeta et al, 2016), pay equivalence, competitiveness and cohesion (Galbraith and Garcilazo, 2010), social welfare programs (Parisi, 2017), health level (Andersen, 2015), flexibility of existing workforce (Détang-Dessendre et al, 2016), speed of technology spread and investment in human capital development (Bobonis and Morrow, 2014; Oliskevych, 2015), that are very diverse in different European countries, have a significant effect on their labor market properties.

The goal of this paper is to conduct the investigation of economic activity in Eastern European countries that are characterized by lower than EU average level of labor force participation (Fig. 2). We provide the analysis of nonlinearity in dynamics of percentage of economic active population for Hungary, Bulgaria, Croatia, Slovakia, Romania, Poland and perform the econometric analysis using smooth transition time series models that are flexible and can capture various kinds of behavior for different modes.

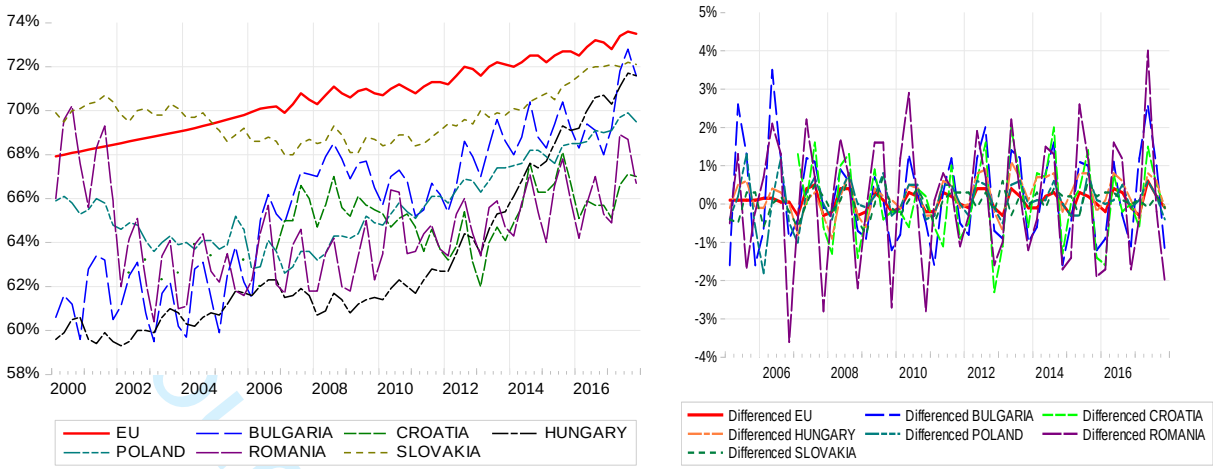


Fig. 2. Dynamics of labor force participation rate (LFPR) and their growth in Eastern European countries during 2000–2017

Source: EUROSTAT Database, authors' elaboration.

The smooth transition regression models are used in recent scientific works to reveal the nonlinearity of time series dynamic properties and investigate the distinctive modes of behavior. Fahmy (2014) studied the nonlinearities in commodity prices, built the smooth transition regression (STR) model with exogenous transition variables in addition to the standard autoregressive lags, and considered inflation rate and oil price in order to captured the regime switching behavior. Zhang (2013) estimated smooth transition error correction model to indicate the significant regime-switching behavior of inflation. Alizadeh et al. (2015) evaluated smooth transition regression (STR) model and proved the nonlinear effects of external debt on economic growth emphasizing existence of two regime structures with some threshold level. Zortuk and Çeken (2016) focused on an inverted U-shaped relationship between environmental pollution and economic development in the transition European economies. They investigated the relationship between carbon dioxide emissions, gross domestic product, energy usage and urban population that was tested by panel smooth transition regression in order to examine the Environmental Kuznets Curve. Belke and Wagemester (2017) built the exponential and logistic variant of a smooth transition regression model to study the reaction of exports market to changes in domestic demand for six Euro area countries. They found that domestic demand fluctuation and uncertainty are important for short-run export dynamics especially over extreme phases of business cycle.

The number of studies emphasized the nonlinearity of processes on labor markets. Donayre and Panovska (2018) suggested a nonlinear econometric approach to investigate the relationship between unemployment changes over the business cycle and wage growth. They estimated the threshold vector autoregressive model with multiple threshold parameters and revealed strong negative correlation among wage growth and unemployment rate during of expansion periods. Oh (2018) examined the flexible labor market hypothesis focusing on firing decision of firms during economic downturns and suggested the nonlinearity of Okun's law. Caporale and Gil-Alana (2007) suggested the model that encompassed asymmetry and long memory of US unemployment rate, fractional integration processes and nonlinearities simultaneously and included the nonlinear function of labor demand, real oil prices and real interest rates.

The scientists used nonlinear transition econometric models and found different regimes of behavior unemployment rate and labor force participation over the business cycle phases. Cuestas, Monfort and Ordóñez (2015) applied a nonlinear logistic smooth transition autoregression system to study common forces that affect the cyclical pattern of unemployment rates in Central and Eastern Europe. They identified convergence clubs in unemployment dynamics and institutional divergences among countries. Cengiz and Sahin (2014) studied the tightness of the labor market and dynamics of labor participation taking into account gender differences. They built the smooth

autoregressive transition models for Turkish labor market to describe an asymmetric pattern of behavior its indicators. Salamaliki and Venetis (2014) used smooth transition trend models to examine the long-run behavior of USA population economic activity. They investigated long-run growth in labor force participation by gender- and age-specific groups and its stationary fluctuations around smooth transitions in linear trend. Gehrke and Hochmuth (2017) focus on the discretionary short-time work as example of labor market policy that prevented layoffs during recession. They examined firms' decision in OECD countries using a smooth transition vector autoregressive model and revealed strong time dependency of this policy as well as its nonlinearity over the business cycle.

This paper delves into studying of labor force participation rate (LFPR) for six Eastern European countries during 2000–2017 and provide the investigation by a smooth transition autoregressive approach in order to examine the variety of behavior in the different regimes for contractionary and expansionary phases of business cycle and to emphasize the nonlinearity and asymmetry of its dynamics.

2 Data Analysis and Methodology

In order to provide the relevant econometric analysis of economic activity of working age population on labor market, we conducted a preliminary statistical analysis of LFPR time series properties that included the investigation of stationarity. We performed the study of ***LFPR*** series stationarity for Eastern Europe countries on the basis of augmented Dickey-Fuller unit root test. The results, presented in Table 1, showed that the percentage of working age population participating in the labor force is nonstationary in levels for all countries. However, the first differences of series demonstrate different statistical properties for different countries. The ***LFPR*** in Croatia and Romania show the existing of unit root and strong its rejection for Δ***LFPR***. The ***LFPR*** series of Bulgaria, Poland and Slovakia are also a first order integrated processes whereas for Hungary we cannot strongly reject the unit root hypothesis for first differences. The nonstationary property of labor force participation rates could be caused by structural changes on labor market. This indicate the risk that unemployment in the long run may not transform in employment so the unemployment rate is not the main indicator of jobless on the labor market (Gustavsson, 2012). The conducted testing results show that the ***LFPR*** series are nonstationary, and therefore labor supply response to macroeconomic shocks can vary depending on job prospects.

Table 1

The results of stationarity tests for labor force participant rate in EU countries

Exogenous variable	Country	ADF-statistics	AR lag	*p*-value
The null hypothesis: ***LFPR*** contains unit root				
Intercept, linear trend	BULGARIA	-3.1104	4	0.1124
	CROATIA	-3.0608	0	0.1282
	HUNGARY	-0.9466	4	0.9443
	POLAND	-2.0416	2	0.5683
	ROMANIA	-2.0702	4	0.5530
	SLOVAKIA	-0.9321	4	0.9462
The null hypothesis: Δ***LFPR*** contains unit root				
Intercept	BULGARIA	-2.8620	3	0.0553
	CROATIA	-8.0243	1	0.0000
	HUNGARY	-2.2364	3	0.0956
	POLAND	-2.8358	3	0.0587
	ROMANIA	-3.5431	3	0.0095
	SLOVAKIA	-2.9460	3	0.0451

Source: authors' evaluation.

Since $LFPR_t$ series are integrated of first order, and the series of first differences, determining the growth of the economic active population share, are stationary (Table 1), the modeling has to be performed for a Δ *LFPR* series.

The number of previous researches found that the labor force participation as well as other labor market indicators respond distinctive to positive and negative disturbances. Negative shocks have larger and more persisted impact on the change in economic active labor share than positive (Lukianenko and Oliskevych, 2017). Indicated asymmetry in the behavior detect the necessity of nonlinear econometric analysis and development of modern time series models to investigate the economic activity on EU labor market.

Taking into consideration the preliminary conducted econometric analysis, we chose a smooth transition regression modeling approach (STR model) to model the dynamics of labor force participation rate in European countries. Smooth transition regression is a nonlinear model that can be considered as some extension of switching regression model. In addition, smooth transition autoregressive model (STAR) takes the advantage in comparison with threshold autoregressive model by providing a possibility to catch smooth transition between different regimes.

A smooth transition regression model (STR model) has the following general representation (Lutkepohl and Kratzig, 2004)

$$X_t = \varphi' Y_t + \theta' Y_t\, G(TV_t;\, \gamma,\, \mu) + \varepsilon_t = (\varphi + \theta\, G(TV_t;\, \gamma,\, \mu))'\, Y_t + \varepsilon_t, \quad t=1,\ldots,T, \qquad (1)$$

where $Y_t=(XL_t', Z_t')'$ is the vector of explanatory variables, $XL_t'=(1, X_{t-1}, \ldots, X_{t-p})'$, $Z_t'=(Z_{1t}, \ldots, Z_{mt})'$ are the vectors of exogenous variables, $\varphi=(\varphi_0, \varphi_1,\ldots, \varphi_s)'$ and $\theta=(\theta_0, \theta_1, \ldots, \theta_s)'$ are $(s+1)$-dimensional vectors of unknown parameters $(s=1+p+m)$, $\varepsilon_t \sim iid(0,\sigma_\varepsilon^2)$ is an sequence of random shock variables. The function $G(TV_t;\gamma,\mu)$ is transition function. It is presented by continuous bounded function of continuous transition variable TV_t, parameter γ, defining slope, and vector $\mu=(\mu_1, \ldots, \mu_k)'$, defining the location parameters, $\mu_1<\ldots<\mu_k$. Specification (1) represent an time series model with stochastic and time varying coefficients that take the values depending on $\varphi+\theta G(TV_t;\gamma,\mu)$. The values of location parameters are increasing sequence and slope parameter is assuming to be positive.

The first term at the right-hand side of the representation (1), $\varphi' Y_t$, describes the linear component of the system and is characterized by parameters φ_j $(j=1,\ldots,s)$ whereas the second term, $\theta' Y_t G(TV_t;\gamma,\mu)$, belong to the non-linear component that is characterized by parameters θ_j.

In case the model (1) don't includes any exogenous variables, the vector Y_t comprises only a constant term and p lags of endogenous variable, $XL_t'=(1,X_{t-1}, \ldots, X_{t-p})'$. If transition variable represents some lag of X, $TV_t=X_{t-j}$, or lag of its first differences, $TV_t=\Delta X_{t-j}$, $j>0$, the model (1) serves as one-dimensional smooth transition autoregressive model. Hence, vectors of parameters φ and θ consist with $p+1$ coefficients, including intercept and p slope parameters by lags of time series variable.

The transition function that describes the nonlinear part of dynamics can be defined by means of logistic function as follows

$$G(TV_t;\, \gamma,\mu) = 1/\,(1+\exp\,(-\gamma \textstyle\prod_{i=1}^{k}(TV_t - \mu_i))), \quad \gamma>0. \qquad (2)$$

In this case, we obtain a logistic smooth transition regression model. Usually in empirical research, it is relevant to take values $k=1$ or $k=2$. Hence, the models are noted as LSTR1 and LSTR2 models, respectively (Terasvirta, 1994). If $k=1$ the parameters of models, $\varphi+\theta G(TV_t;\gamma,\mu)$, increase monotonously with VT_t from starting value φ to maximum value $\varphi+\theta$. If $k=2$ the parameters are described by the function that is symmetric around the midpoint $(\mu_1+\mu_2)/2$. In this case, the logistic function reaches the minimum value that lies between zero and 1/2. The transition function approach zero when $\gamma\to\infty$ and takes value 1/2 when $\mu_1=\mu_2$ and $\gamma<\infty$. Therefore, the parameter γ indicates the slope and μ_1, μ_2 indicate the allocation of transition function values.

In practical modeling, the transition variable TV_t is usually stochastic and represents some term of vector Y_t. It also can represent the differences of elements Y_t or some linear combination of variables. If TV_t describes trend the model is characterized by deterministically varying parameters.

To determine the correct type of nonlinear smooth transition model, we applied a common approach that acompasses testing the null hypothesis of linearity under the alternative hypothesis of

LSTR-nonlinearity. We used an approximation of transition function (2) by third-order Taylor representation under the null hypothesis γ=0. Therefore, the following auxiliary regressions were estimated (Lutkepohl and Kratzig, 2004)

$$X_t = \alpha_0' Y_t + \sum_{i=1}^{3} \alpha_i' Y_t^{\sim} (TV_t)^i + u^{\sim}_t, \qquad t=1,\ldots,T, \tag{3}$$

where $Y_t=(1,\ Y_t^{\sim})'$, $Y_t^{\sim}$ is s-dimensional vector, $u^{\sim}_t = u_t + \theta' Y_t R_3(TV_t;\gamma,\mu)$, $R_3(TV_t;\gamma,\mu)$ is remainder of approximation. Parameters α_i (i=1,2,3) are represented by $\gamma\beta_i$, where β_i are functions of θ and μ. The null hypothesis of linearity is H_0: $\alpha_1=\alpha_2=\alpha_3=0$. Under the null hypothesis, the distribution of test statistic is approximated with $F[3,T-4s-1]$ Fisher distribution.

3. Econometric Results

We use LSTAR modeling approach to conduct the one-dimensional econometric investigation of labor force participant rate, *LFPR*, in European countries. The number of lags, included into the model, were indicated by means of Akaike, Schwarz and Hannan-Quinn statistical criteria's, calculated for different corresponded linear models. Additionally, we include in model seasonal variables *S1*, *S2*, *S3* that take the values 1 in the first, second and third quarters, respectively, and zero for all other quarters. These seasonal variables give as possibility to take into account seasonal factors that exhibit *LFPR* series (Fig. 2).

To determine the relevant LSTR specifications for labor force participant rate, we indicate the set of potential transition variables $Q=\{Trend,\ \Delta LFPR_{t-1},\ \Delta LFPR_{t-2}\}$ and next perform nonlinearity tests choosing each variable from list Q as transition variable. The testing procedure included three steps (Table 2). At first, we checked the null hypothesis H_{04}: $\alpha_3=0$ (statistics *F4*). Secondly, we tested the null hypothesis H_{03}: $\alpha_2=0$ under restriction $\alpha_3=0$ (statistics *F3*). Next, we tested the null hypothesis H_{02}: $\alpha_1=0$ under restriction $\alpha_3=\alpha_2=0$ (statistics *F2*). If $\mu=0$ the model LSTR1 satisfy $\alpha_2=0$ whereas the model LSTR2 reveals $\alpha_1=\alpha_3=0$ (Lutkepohl and Kratzig, 2004). If $\mu\neq0$ the α_2 is still closer to zero than α_1 or α_3 for LSTR1 model and vice versa for LSTR2 model. The results of nonlinearity tests sequence for different transition variables and different countries are given in Table 2.

The results revealed nonlinearity in behavior of labor force participation rate for all countries except Croatia. For Hungary, Romania and Slovakia, we received similar results that suggested the LSTR1 model with transition variable *TREND* as appropriate model. For Bulgaria, we can consider two models LSTR1 with transition variable $\Delta LFPR_{t-2}$ and LSRT2 model with transition variable *Trend*. LSTR1 model describes the asymmetric behavior of economic activity on the labor market and indicates that process properties depend on the phase of the business cycle in which the economy is being. Additionally, the model take into account that the transition from one behavior regime to another occurs smoothly. Model LSTR2 with trend variable as a transition variable, indicate that the dynamic properties of the process is similar for large and small values of economic activity, but different in the middle. The estimation of the initial values of the parameters γ and μ, and further evaluation and diagnosis of different smooth transition models discover that LSTR1 model with transition variable $\Delta LFPR_{t-2}$ is the best to describe the rate of growth of the economically active population share for Bulgaria.

Polish labor market revealed some distinctive properties. The *LFPR* of Poland exhibit nonlinear dynamics for all three transition variables. However, the least p-value was obtained for LSTR2 model with transition variable $\Delta LFPR_{t-2}$. Moreover, using LSTR2 nonlinear model, it is possible to describe nonlinear short-term fluctuations when the adjustment force is a nonlinear function depended on the deviation from equilibrium conditions.

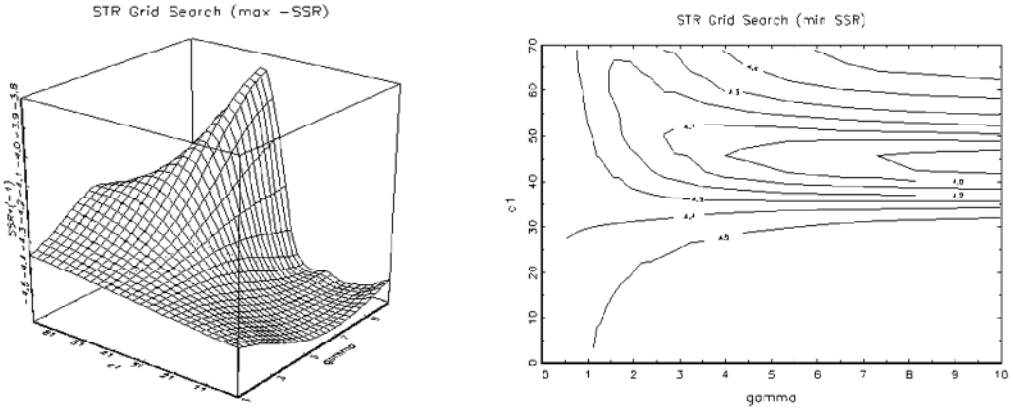
Table 2

The Results of Nonlinearity Testing Procedure

Transition variable	*p*-value *F* (H_0)	*p*-value *F4* (H_{04})	*p*-value *F3* (H_{03})	*p*-value *F2* (H_{02})	Adequate model
BULGARY					
Δ*LFPR*(-1)	0.0934	0.9808	0.6582	0.0057***	Linear
Δ*LFPR*(-2)	0.0195**	0.5271	0.2618	0.0032***	LSTR1
Trend	0.0178**	0.9486	0.0037***	0.0867***	LSTR2
CROATIA					
Δ*LFPR*(-1)	0.3861	0.5086	0.4773	0.1613	Linear
Δ*LFPR*(-2)	0.7177	0.4994	0.9874	0.3113	Linear
Trend	0.7746	0.5463	0.5476	0.7263	Linear
HUNGARY					
Δ*LFPR*(-1)	0.5831	0.8958	0.2963	0.3482	Linear
Δ*LFPR*(-2)	0.8721	0.9340	0.4900	0.6277	Linear
Trend	0.0369**	0.7099	0.6126	0.0015***	LSTR1
POLAND					
Δ*LFPR*(-1)	0.0059***	0.4801	0.4996	0.0003***	LSTR1
Δ*LFPR*(-2)	0.0017***	0.1778	0.0022***	0.0622*	LSTR2
Trend	0.0118**	0.7841	0.1821	0.0011***	LSTR1
ROMANIA					
Δ*LFPR*(-1)	0.6554	0.4148	0.6349	0.4776	Linear
Δ*LFPR*(-2)	0.5133	0.2840	0.4394	0.5984	Linear
Trend	0.0382**	0.2268	0.0921*	0.0681*	LSTR1
SLOVAKIA					
Δ*LFPR*(-1)	0.6470	0.4287	0.5832	0.4903	Linear
Δ*LFPR*(-2)	0.0820*	0.3530	0.0118**	0.9060	Linear
Trend	0.0215**	0.0731*	0.2355	0.0395**	LSTR1

Note: * denotes statistical significance at 10%, **– at 5%, ***– at 1%.
Source: authors' evaluations.

Figure 3 shows the residual sum of squares (SSR) as a functions of two parameters γ and μ for estimated model for Slovakia. In particular, Fig. 3a present a surface –SSR and, therefore, indicates its maximum, and Fig. 3b shows an indifference curves of SSR function that allow to found out the minimum of residual squares sum. The Fig. 4 and Fig. 5 represent SSR for Bulgaria and Poland, respectively.



a b

Fig. 3. Graphic representation of residual sum of squares as a function of the slope and allocation parameter for LSTR1 model for Slovakia

Source: authors' evaluations.

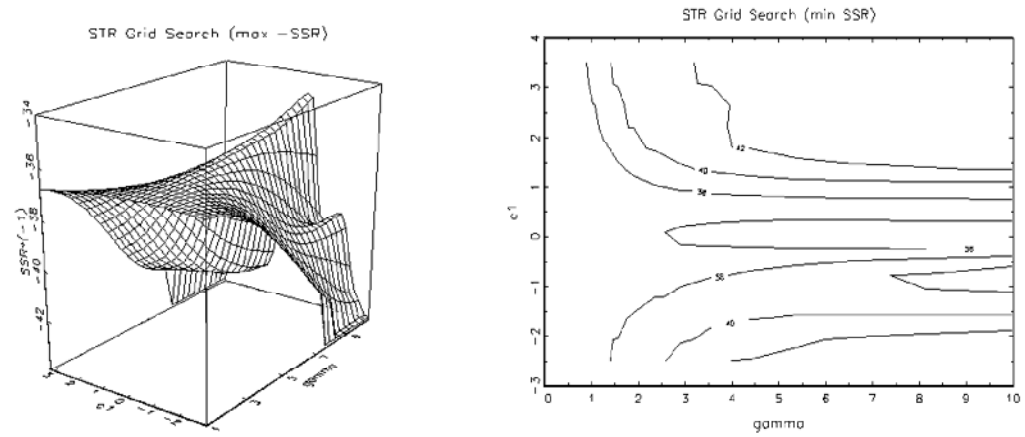


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Fig. 4. Graphic representation of residual sum of squares as a function of the slope and allocation parameter for LSTR1 model for Bulgaria

Source: authors' evaluations.

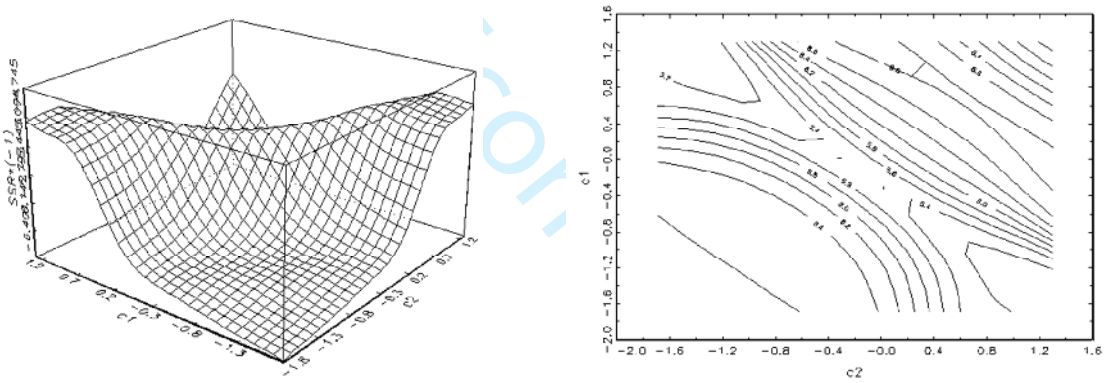

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Fig. 5. Graphic representation of residual sum of squares as a function of allocation parameters for LSTR2 model for Poland

Source: authors' evaluations.

Nevertheless, we obtained evidence of nonlinearity for most EU countries, however, the model specification for different countries are quite different. The final LSTAR models for the labor force participant rate are the following:

Slovakia (LSTR1) :

$$\Delta LFPR_t = \varphi_0 + \alpha_1 S1_t + \alpha_2 S2_t + \alpha_3 S3_t + \varphi_1 \Delta LFPR_{t-1} + \varphi_2 \Delta LFPR_{t-2} + \\ + G(TREND; \gamma,\mu)\cdot(\theta_1 \Delta LFPR_{t-1} + \theta_2 \Delta LFPR_{t-2}) + \varepsilon_t, \quad (4)$$

$$G(TREND; \gamma,\mu) = 1/ (1+\exp(-\gamma (TREND-\mu))), \quad (5)$$

Bulgaria (LSTR1) :

$$\Delta LFPR_t = \varphi_0 + \alpha_1 S1_t + \alpha_2 S2_t + \alpha_3 S3_t + \varphi_1 \Delta LFPR_{t-1} + \varphi_2 \Delta LFPR_{t-2} + \\ + G(\Delta LFPR_{t-2}; \gamma,\mu)\cdot(\theta_1 \Delta LFPR_{t-1} + \theta_2 \Delta LFPR_{t-2}) + \varepsilon_t, \quad (6)$$

$$G(\Delta LFPR_{t-2}; \gamma, \mu) = 1/ (1+\exp(-\gamma (\Delta LFPR_{t-2} - \mu))), \quad (7)$$

Poland (LSTR2) :

$$\Delta LFPR_t = \varphi_0 + \alpha_1 S1_t + \alpha_2 S2_t + \alpha_3 S3_t + \varphi_1 \Delta LFPR_{t-1} + \varphi_2 \Delta LFPR_{t-2} + \\ + G(\Delta LFPR_{t-2}; \gamma,\mu_1,\mu_2)\cdot(\theta_1 \Delta LFPR_{t-1} + \theta_2 \Delta LFPR_{t-2}) + \varepsilon_t, \quad (8)$$

$$G(\Delta LFPR_{t-2}; \gamma,\mu_1,\mu_2) = 1/ (1+\exp(-\gamma (\Delta LFPR_{t-2}-\mu_1)(\Delta LFPR_{t-2}-\mu_2))). \quad (9)$$

where $\varepsilon_t \sim iid(0,\sigma^2)$, G bounded with zero and one transition functions. Transition functions (5) and (7) are monotonically increasing with respect to ***TREND*** and $\Delta LFPR_{t-2}$, respectively. Slope parameters γ indicate how quickly the transition from 0 to 1 occurs whereas the allocation parameters μ determine points where the transition takes place.

The results of parameters estimation of LSTR models for Romania and Bulgaria are shown in Table 3. Estimation of nonlinear model was based on the maximization of conditional likelihood using a Newton-Raphson algorithm.

Table 3

The Estimation Results of LSTR1 models for Labor Force Participation Rate

Variable	Linear part of LSTAR model		Nonlinear part of LSTAR model	
	Coefficient [t-statistic] {p-value}	Coefficient [t-statistic] {p-value}	Coefficient [t-statistic] {p-value}	Coefficient [t-statistic] {p-value}
	ROMANIA	BULGARIA	ROMANIA	BULGARIA
Const	-1.75324 [-4.8037] {0.0000}	-1.20347 [-4.1843] {0.0001}	—	—
S1	0.91100 [1.7454] {0.0861}	1.30628 [3.4596] {0.0010}	—	—
S2	3.62723 [5.4049] {0.0000}	1.68139 [3.9684] {0.0002}	—	—
S3	2.51206 [5.1107] {0.0000}	1.66213 [4.8195] {0.0000}	—	—
$\Delta LFPR(-1)$	0.26110 [1.3056] {0.1968}	-0.20326 [-1.6934] {0.0956}	-0.46509 [-2.3123] {0.0243}	0.65881 [3.7526] {0.0004}
$\Delta LFPR(-2)$	-0.36454 [-2.1554] {0.0352}	-0.77920 [-3.3578] {0.0014}	0.26223 [1.4532] {0.1515}	0.53378 [1.7886] {0.0788}
Parameters of transition function				
γ	—	—	10.00000 [0.9653] {0.3383}	10.00000 [0.4620] {0.6458}
μ	—	—	10.37931 [3.1675] {0.0024}	0.07931 [-0.4884] {0.6271}

Source: authors' estimation.

Modeling reveals that the current rate of these changes responds differently to changes in the previous characteristics. Estimated values of the distribution parameter μ indicate the values at which the smooth changes in the dynamic of labor force economic activity from the periods of low growth rates to periods of high values happen. The estimated slope parameters γ determine the steepness of transition smoothness between regimes. The high values show that the economic activity of labor force quickly reacts to changes that disturb the labor market in the past.

Comparison of modeling results for conducted nonlinear LSTR models with linear autoregressive models showed a significant decrease of information criteria's as well as increase for coefficients of determination that confirm the advantages of usage of nonlinear modeling approach for all counties. Fig. 6 shows fitting results of LSTR1 model for Hungary.

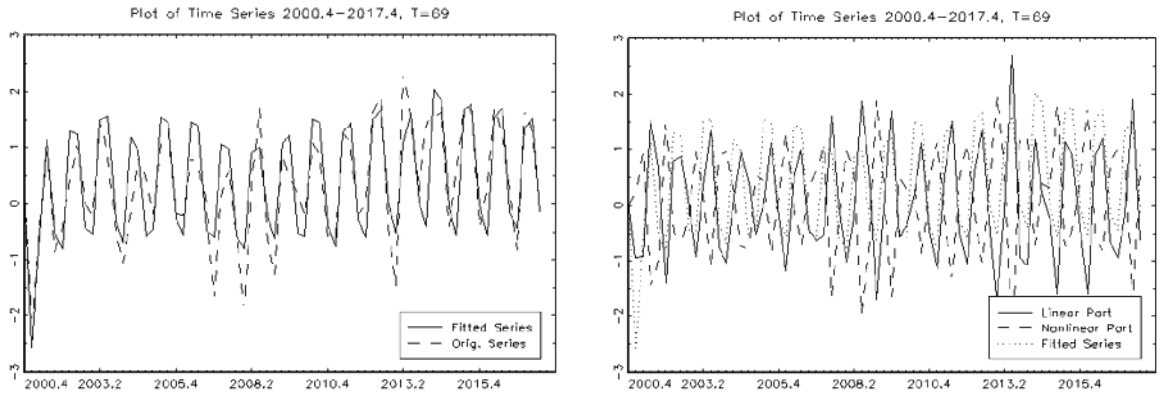

Fig. 6. The dynamics of actual ΔLFPR, its fitted by LSTR1 model values, estimated dynamics of linear and nonlinear part of series for Hungary

Source: authors' estimation.

We provide the adequacy verification of conducted modeling by means of number testing procedures. At first, we test whether the models adequately characterize the nonlinearity that was originally found in the data and check the possibility of existence some additional nonlinearity that could be unmodeled and remained (Table 4). Besides test of the residual nonlinearity, we evaluate parameters stability of estimated LSTR models (Table 4) by means of auxiliary regressions (Lutkepohl and Kratzig, 2004).

Table 4

The results of LSTR models adequacy verification

Test of no additive nonlinearity	Country	p-value F	p-value F4	p-value F3	p-value F2
	HUNGARY	0.8548	0.7718	0.5398	0.6436
	POLAND	0.7555	0.7102	0.2867	0.8984
	BULGARIA	0,3624	0,6445	0,6416	0,9149
	ROMANIA	0.1049	0.9480	0.1989	0.2645
	SLOVAKIA	0.4497	0.2358	0.4815	0.5068
Test of parameter constancy	Country	Transition function	Test statistic	Distribution	p-value
	HUNGARY	H_1	1.2217	F[4;53]	0.3127
		H_2	0.7798	F[8;49]	0.6223
	POLAND	H_1	1.0427	F[4;53]	0.3940
		H_2	0.6783	F[8;49]	0.7082
	BULGARIA	H_1	1,9168	F[11,19]	0,1212
		H_2	2.1522	F[22,8]	0,4810
	ROMANIA	H_1	0.9191	F[4;53]	0.4598
		H_2	0.5670	F[8;49]	0.7996
	SLOVAKIA	H_1	0.9979	F[4;53]	0.5234
		H_2	0.7825	F[8;49]	0.6651

Source: evaluations of the authors.

It is also necessary to conduct the diagnostic procedures of the estimated models that include number of evaluation concerning the existence of autocorrelation in residuals, conditional heteroscedasticity (ARCH effects) as well as normality of their distribution (Table 5).

Table 5

The Results of Diagnostic Test for conducted LSTR models

	Country	Lags order	Test statistic	Distribution	*p*-value
LM-test of autocorrelation	HUNGARY	1	2.3494	F[1,57]	0.1309
		2	1.5232	F[2,55]	0.2271
	POLAND	1	0.3942	F[1,56]	0.5327
		2	0.9711	F[2,54]	0.3852
	BULGARIA	1	0.7969	F[1,57]	0.3758
		2	1.9979	F[2,55]	0.1453
	ROMANIA	1	1.4942	F[1,57]	0.2266
		2	1.1907	F[2,55]	0.3117
	SLOVAKIA	1	0.1886	F[1,57]	0.6657
		2	1.8151	F[2,55]	0.1723
ARCH-LM test (8 lags)	Country	χ^2-statistics	*p*-value	*F*-statistics	*p*-value
	HUNGARY	10.7384	0.0297	3.2159	0.0185
	POLAND	0.9045	0.9239	0.2293	0.9209
	BULGARIA	3.1495	0.5331	0.8275	0.5129
	ROMANIA	2.5552	0.6348	0.6649	0.6188
	SLOVAKIA	5.9059	0.6578	0.8174	0.5908
Normality test	Country	Skewness	Kurtosis	Jarque–Bera statistics	*p*-value
	HUNGARY	0.4097	4.2980	6.7737	0.0338
	POLAND	-0.3951	3.2208	1.9350	0.3800
	BULGARIA	0.6274	4.0538	7.7198	0.0211
	ROMANIA	-0.3295	3.3052	1.5162	0.4685
	SLOVAKIA	-0.0421	2.6147	0.4471	0.7997

Source: authors' evaluations.

The results of statistical tests approved the correctness of conducted modeling, confirmed the adequacy of smooth transition nonlinear logistic models that discovered the nonlinear peculiarities of labor force participation dynamics in investigated Eastern European countries.

6 Conclusions

Over the last decades, the dynamics of European labor force activity showed considerable fluctuations and asymmetric behavior during business cycle despite of overall increasing trend. The dynamic pattern of labor force participation rate demonstrated significant differences for different countries that reflected variety desirability and alacrity to work level within Europe. Strong negative disturbances that took place in 2008 – 2009 caused negative impacts on economic activity of population in searching job because of unfavorable expectations but these effects were not inherent for all the regions. Some countries demonstrated rising of labor force participation rate even during recession.

In order to indicate the nonlinearity in dynamics of labor force economic activity, we applied the smooth transition autoregressive approach that provide us the opportunity to describe various dynamic properties of process during periods of expansion and recession. We examined labor markets of six Eastern European countries, Hungary, Bulgaria, Poland, Slovakia, Romania and Croatia, that are characterized by lower lever of labor force participation than average level in EU. The results of modeling quantitatively characterized smooth changes in the behavior modes of labor force activity. The estimated slope parameters that determine the smoothness of transition between regimes showed that, in all countries, the population economic activity quite quickly reacts to changes that occurred on the labor market in the past. During recession periods, households of European countries that joint EU last decade in order to prevent the depletion of their total income increase labor supply and showed increased activity in job search. However, this positive trend in

the labor market reactivation in these countries is not sufficient to catch the level of willingness to work that exhibit the developed European countries.

Increase of population activity on labor market would create a great contribute in development of domestic labor markets, efficiency distribution of employment, relevant retraining and professional development of human capital in each country as well as in Euro area in general.

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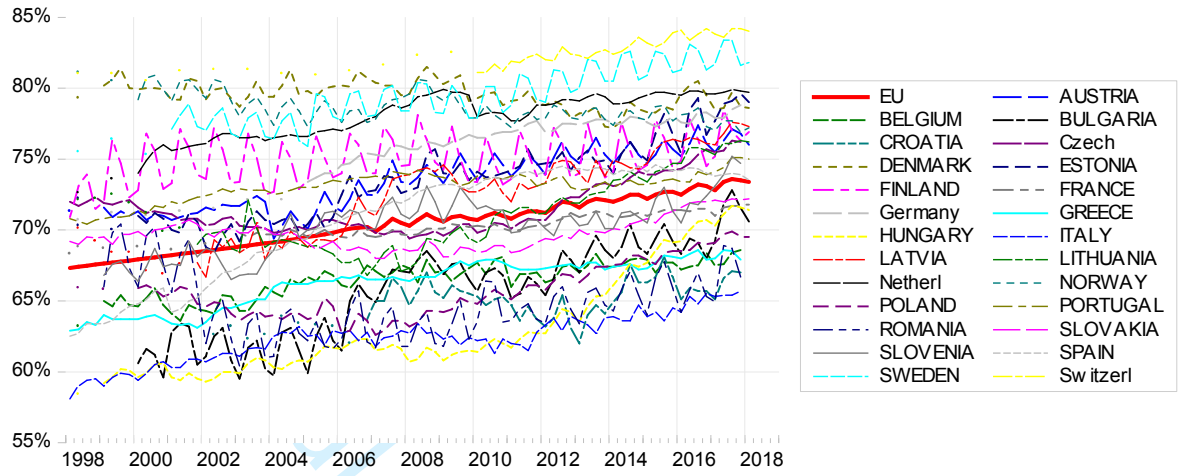
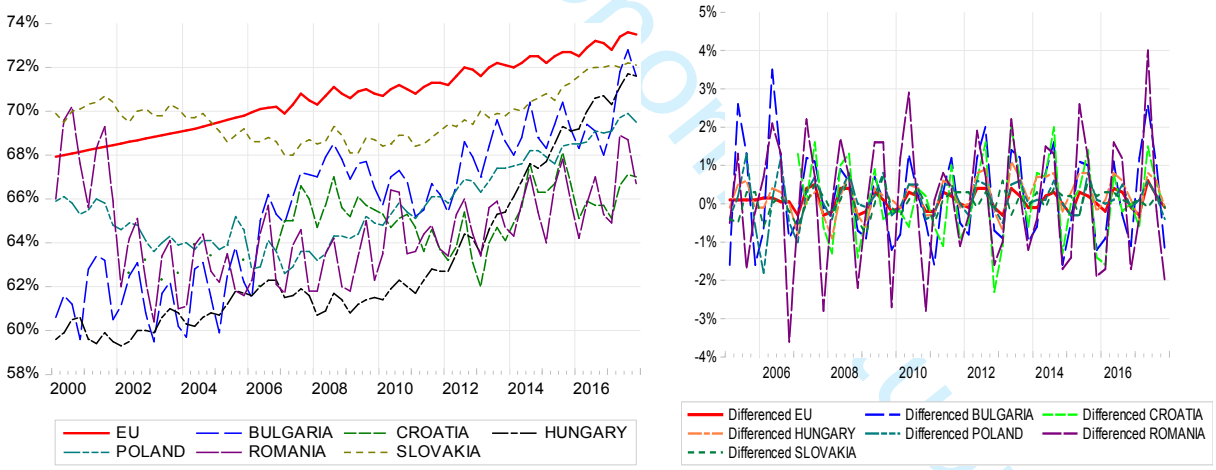
Figure 1
Dynamics of population economic activity on labor markets of European countries during 1998–2017



Source: data from EUROSTAT Database, authors' elaborations.

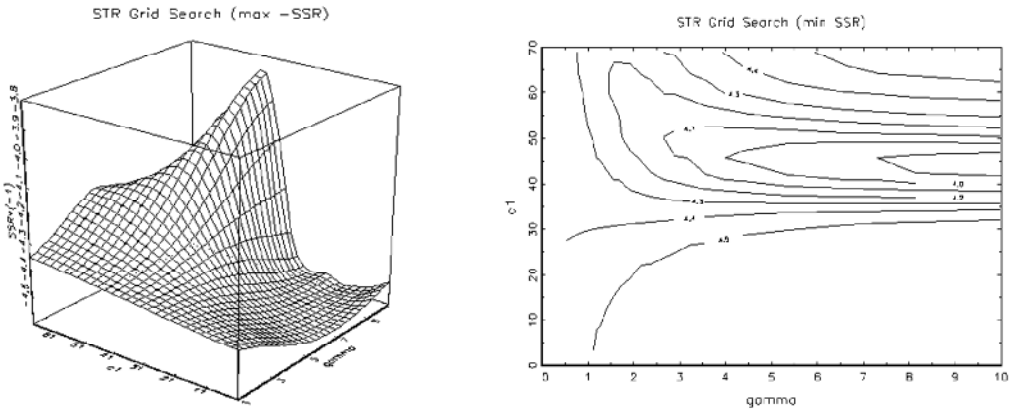
Figure 2
Dynamics of labor force participation rate (LFPR) and their growth in Eastern European countries during 2000–2017



Source: data from EUROSTAT Database, authors' elaboration.

Figure 3
Graphic representation of residual sum of squares as a function of the slope and allocation parameter for LSTR1 model for Slovakia

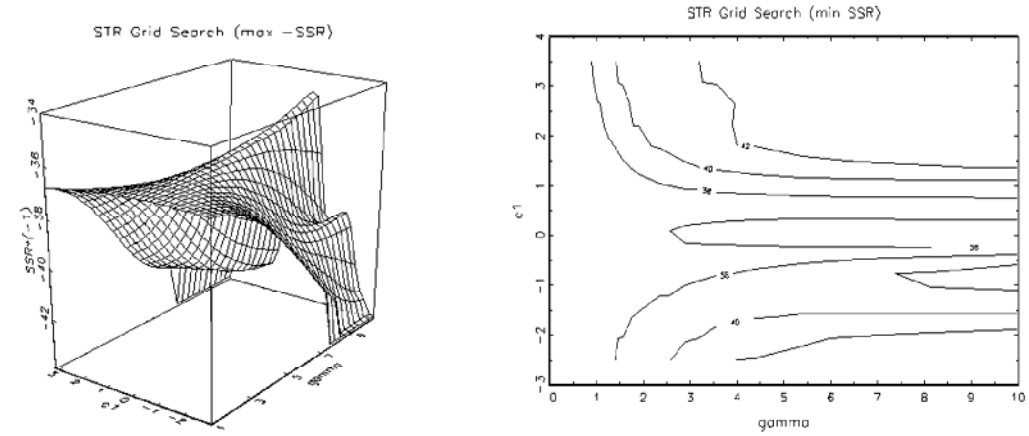
a b



Source: authors' evaluations.

Figure 4
Graphic representation of residual sum of squares as a function of the slope and allocation parameter for LSTR1 model for Bulgaria

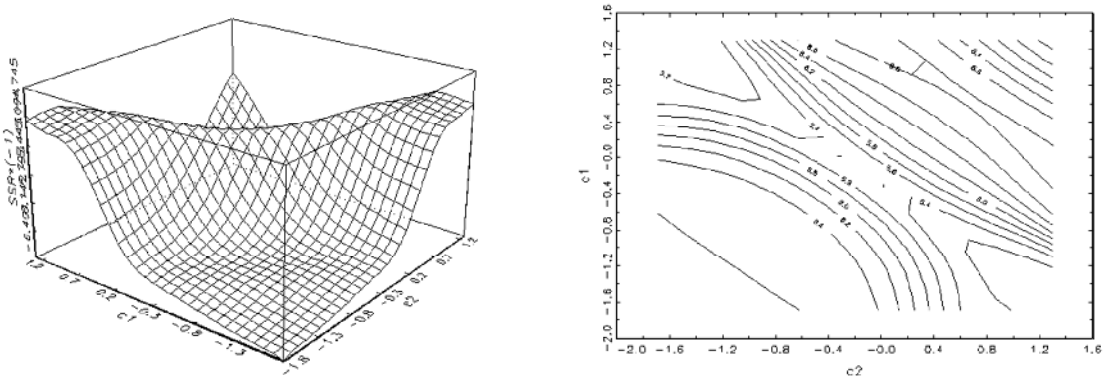
a b



Source: authors' evaluations.

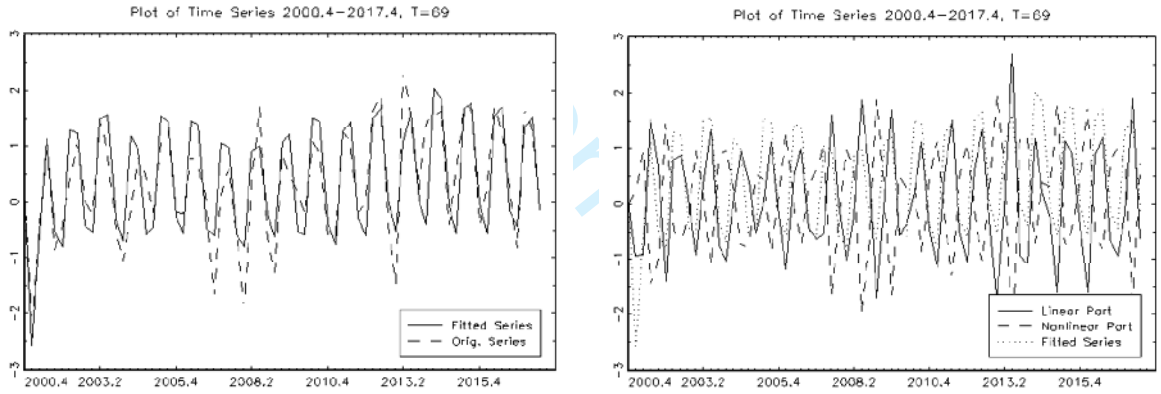
Figure 5
Graphic representation of residual sum of squares as a function of allocation parameters for LSTR2 model for Poland

a b



Source: authors' evaluations.

Figure 6
The dynamics of actual Δ LFPR, its fitted by LSTR1 model values, estimated dynamics of linear and nonlinear part of series for Hungary



Source: authors' estimation.

Table 1

The results of stationarity tests for labor force participant rate in EU countries

Exogenous variable	Country	ADF-statistics	AR lag	*p*-value
The null hypothesis: *LFPR* contains unit root				
Intercept, linear trend	BULGARIA	-3.1104	4	0.1124
	CROATIA	-3.0608	0	0.1282
	HUNGARY	-0.9466	4	0.9443
	POLAND	-2.0416	2	0.5683
	ROMANIA	-2.0702	4	0.5530
	SLOVAKIA	-0.9321	4	0.9462
The null hypothesis: Δ *LFPR* contains unit root				
Intercept	BULGARIA	-2.8620	3	0.0553
	CROATIA	-8.0243	1	0.0000
	HUNGARY	-2.2364	3	0.0956
	POLAND	-2.8358	3	0.0587
	ROMANIA	-3.5431	3	0.0095
	SLOVAKIA	-2.9460	3	0.0451

Source: authors' evaluation.

Table 2

The Results of Nonlinearity Testing Procedure

Transition variable	*p*-value *F* (H_0)	*p*-value *F4* (H_{04})	*p*-value *F3* (H_{03})	*p*-value *F2* (H_{02})	Adequate model
BULGARY					
Δ *LFPR*(-1)	0.0934	0.9808	0.6582	0.0057***	Linear
Δ *LFPR*(-2)	0.0195**	0.5271	0.2618	0.0032***	LSTR1
Trend	0.0178**	0.9486	0.0037***	0.0867***	LSTR2
CROATIA					
Δ *LFPR*(-1)	0.3861	0.5086	0.4773	0.1613	Linear
Δ *LFPR*(-2)	0.7177	0.4994	0.9874	0.3113	Linear
Trend	0.7746	0.5463	0.5476	0.7263	Linear
HUNGARY					
Δ *LFPR*(-1)	0.5831	0.8958	0.2963	0.3482	Linear
Δ *LFPR*(-2)	0.8721	0.9340	0.4900	0.6277	Linear
Trend	0.0369**	0.7099	0.6126	0.0015***	LSTR1
POLAND					
Δ *LFPR*(-1)	0.0059***	0.4801	0.4996	0.0003***	LSTR1
Δ *LFPR*(-2)	0.0017***	0.1778	0.0022***	0.0622*	LSTR2
Trend	0.0118**	0.7841	0.1821	0.0011***	LSTR1
ROMANIA					
Δ *LFPR*(-1)	0.6554	0.4148	0.6349	0.4776	Linear
Δ *LFPR*(-2)	0.5133	0.2840	0.4394	0.5984	Linear
Trend	0.0382**	0.2268	0.0921*	0.0681*	LSTR1
SLOVAKIA					
Δ *LFPR*(-1)	0.6470	0.4287	0.5832	0.4903	Linear
Δ *LFPR*(-2)	0.0820*	0.3530	0.0118**	0.9060	Linear
Trend	0.0215**	0.0731*	0.2355	0.0395**	LSTR1

Note: * denotes statistical significance at 10%, ** – at 5%, *** – at 1%.
Source: authors' evaluations.

Table 3
The Estimation Results of LSTR1 models for Labor Force Participation Rate

Variable	Linear part of LSTAR model		Nonlinear part of LSTAR model	
	Coefficient [t-statistic] {p-value}	Coefficient [t-statistic] {p-value}	Coefficient [t-statistic] {p-value}	Coefficient [t-statistic] {p-value}
	ROMANIA	BULGARIA	ROMANIA	BULGARIA
Const	-1.75324 [-4.8037] {0.0000}	-1.20347 [-4.1843] {0.0001}	—	—
S1	0.91100 [1.7454] {0.0861}	1.30628 [3.4596] {0.0010}	—	—
S2	3.62723 [5.4049] {0.0000}	1.68139 [3.9684] {0.0002}	—	—
S3	2.51206 [5.1107] {0.0000}	1.66213 [4.8195] {0.0000}	—	—
Δ *LFPR*(-1)	0.26110 [1.3056] {0.1968}	-0.20326 [-1.6934] {0.0956}	-0.46509 [-2.3123] {0.0243}	0.65881 [3.7526] {0.0004}
Δ *LFPR*(-2)	-0.36454 [-2.1554] {0.0352}	-0.77920 [-3.3578] {0.0014}	0.26223 [1.4532] {0.1515}	0.53378 [1.7886] {0.0788}
Parameters of transition function				
γ	—	—	10.00000 [0.9653] {0.3383}	10.00000 [0.4620] {0.6458}
μ	—	—	10.37931 [3.1675] {0.0024}	0.07931 [-0.4884] {0.6271}

Source: authors' estimation.

Table 4
The results of LSTR models adequacy verification

Test of no additive nonlinearity	Country	p-value F	p- value F4	p- value F3	p- value F2
	HUNGARY	0.8548	0.7718	0.5398	0.6436
	POLAND	0.7555	0.7102	0.2867	0.8984
	BULGARIA	0,3624	0,6445	0,6416	0,9149
	ROMANIA	0.1049	0.9480	0.1989	0.2645
	SLOVAKIA	0.4497	0.2358	0.4815	0.5068
Test of parameter constancy	Country	Transition function	Test statistic	Distribution	p- value
	HUNGARY	H_1	1.2217	F[4;53]	0.3127
		H_2	0.7798	F[8;49]	0.6223
	POLAND	H_1	1.0427	F[4;53]	0.3940
		H_2	0.6783	F[8;49]	0.7082
	BULGARIA	H_1	1,9168	F[11,19]	0,1212
		H_2	2.1522	F[22,8]	0,4810
	ROMANIA	H_1	0.9191	F[4;53]	0.4598
		H_2	0.5670	F[8;49]	0.7996
	SLOVAKIA	H_1	0.9979	F[4;53]	0.5234
		H_2	0.7825	F[8;49]	0.6651

Source: evaluations of the authors.

Table 5
The Results of Diagnostic Test for conducted LSTR models

LM-test of autocorrelation	Country	Lags order	Test statistic	Distribution	*p*-value
	HUNGARY	1	2.3494	F[1,57]	0.1309
		2	1.5232	F[2,55]	0.2271
	POLAND	1	0.3942	F[1,56]	0.5327
		2	0.9711	F[2,54]	0.3852
	BULGARIA	1	0.7969	F[1,57]	0.3758
		2	1.9979	F[2,55]	0.1453
	ROMANIA	1	1.4942	F[1,57]	0.2266
		2	1.1907	F[2,55]	0.3117
	SLOVAKIA	1	0.1886	F[1,57]	0.6657
		2	1.8151	F[2,55]	0.1723
ARCH-LM test (8 lags)	Country	χ^2 - statistics	*p* - value	*F* - statistics	*p* – value
	HUNGARY	10.7384	0.0297	3.2159	0.0185
	POLAND	0.9045	0.9239	0.2293	0.9209
	BULGARIA	3.1495	0.5331	0.8275	0.5129
	ROMANIA	2.5552	0.6348	0.6649	0.6188
	SLOVAKIA	5.9059	0.6578	0.8174	0.5908
Normality test	Country	Skewness	Kurtosis	Jarque–Bera statistics	*p* – value
	HUNGARY	0.4097	4.2980	6.7737	0.0338
	POLAND	-0.3951	3.2208	1.9350	0.3800
	BULGARIA	0.6274	4.0538	7.7198	0.0211
	ROMANIA	-0.3295	3.3052	1.5162	0.4685
	SLOVAKIA	-0.0421	2.6147	0.4471	0.7997

Source: evaluations of the author.