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# Economic Activity of Population in the Ukrainian Labor Market: Nonlinear Smooth Transition Model

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***Author's contribution***

*The sole author designed, analyzed and interpreted and prepared the manuscript.*

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## ABSTRACT

This article presents the econometric analysis of labor force participation rate in Ukraine based on macroeconomic data for 2002—2014 years. In the article was reviewed a nonlinear logistic smooth transition autoregressive model which makes it possible to model the asymmetry in behavior of economic activity of population in the labor market and allows to describe various dynamic properties of the process during periods of expansion and recession. The results of modeling quantitatively characterize smooth changes in the behavior of the time series from periods of low growth rates to periods of high values. The estimated slope parameter which determines the transition smoothness shows that the economic activity of population quickly reacts to changes taking place in the labor market.

*Keywords: Labor market; labor force participation rate; nonlinearity; LSTAR model; Ukraine.*

## 1. INTRODUCTION

During the transformation period of Ukrainian economy a labor market is in a difficult situation, when a considerable part of working population is in search of jobs, which is more often a condition for survival and provision the basis of human existence. In 2014 in Ukraine the largest

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share in total employment has trade, repair, accommodation and food service activities (22%). The share of employment in agriculture, forestry and fishing is 17%, in manufacturing, mining and quarrying –16%, in education – 9%, in human health and social work activities – 6%. Such sectors as construction (4%), transportation and storage (6%), financial and insurance activities (2%), information and communication (2%), real estate activities (2%) are underdeveloped. Among occupational groups the largest share of employment belongs to elementary occupations (24%), then service workers and shop and market sales – 11%, craft and related workers – 7%, professionals – 6%, technicians and associate professionals – 7%, skilled agricultural and fishery workers – 2%.

Internal migration of labor resources among the various regions of the country is very low in Ukraine. However, because of limited employment opportunities, low wages and hard political situation many economically active Ukrainian citizens of working-age become external labor emigrants. The main centers of attraction for Ukrainian labor migrants are Poland, Czech Republic, Russia, Italy and Portugal. For Ukraine these processes can be threatening not only in terms of labor potential use, but also for its formation.

In the present conditions of macroeconomic instability of the economy in Ukraine and strengthening of social tension various forms of unemployment exist as well as its overall level increases. Support for employment is an important condition for the functioning and development of society, the preservation and enhancement of its human capital. Overcoming the crisis on the labor market will contribute to social security of an individual and society from various dangers and will have an influence on social security of the state. Elaboration of strategy of labor market development in Ukraine and creation of effective system of its regulation that are designed for the long term, require investigation of an internal contradictions in the labor sphere, determination of basic quantitative and qualitative parameters of the future labor force.

A number of modern Ukrainian scientists devoted their works to study of problems of employment and its structure. Scientists detect presence of demographic, informational, structural and market imbalances in social and labor relations. These factors lead to establishment of the uneven distribution of human resources in the territory of Ukraine [1], disparity between education system or professional training of specialists and needs of modern production, besides that an uneven demand for age criterion [2], the outflow of highly skilled personnel abroad and illegal emigration. V. Kokhan [3] draws attention to the problems of observance and protection of labor rights of employees involved in non-standard employment, I. Khlevnaya [4] shows existing problems of employment in rural areas. A. Yanishevska [5] investigates problems of the youth labor market, studies level of economic activity, employment and unemployment rates of young people in different regions of Ukraine. Y. Yuryk and I Zhuk [6] point to the negative effects of the financial crisis on the labor demand, real wages and the number of redundant workers as a result of recession, increase of global competition.

## 2. METHODOLOGY

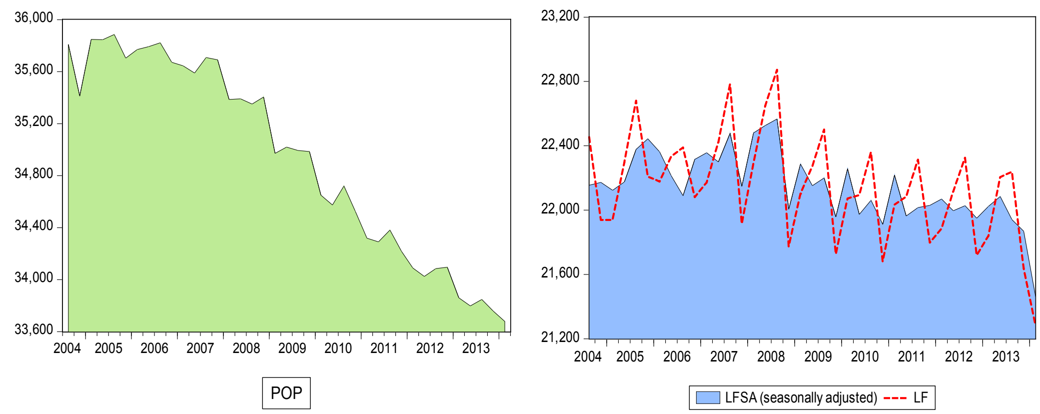
### 2.1 Literature Review and Data

Scholars give a considerable attention to research an existing systematic demographic crisis and narrowing the demographic basis for the recreation of human resources. Among others, Y. Tsizhma [7] put a special focus on the decline in population, reduced life expectancy, fertility decline and negative migration balance, which are the main indicators of the demographic situation in Ukraine and represent a real threat to the national economy and creation of employment potential of society [7]. Statistical analysis shows that the quarterly rate of change of the population aged 15 to 70 years during 2002—2008 was -0.096%, moreover in the period from 2009 to 2013 this indicator fell by half and is -0.20% per quarter (Fig. 1a).

However, at the present stage Ukrainian labor market shows a rapid increase in unemployment, which is characterized by gender and age unevenness, and we can observed difficulty or impossibility of employment for low-skilled workers (youth, women, the disabled) and immigrants from the eastern regions of Ukraine. Analysis of statistical data shows that the unemployment rate (UR), which is defined by the International Labor Organization, after a significant shift due to the crisis in the end of 2008 (average from 6 to 9 percent) during 2009—2013 slightly decreased, but in 2014 it again shows a growing trend.

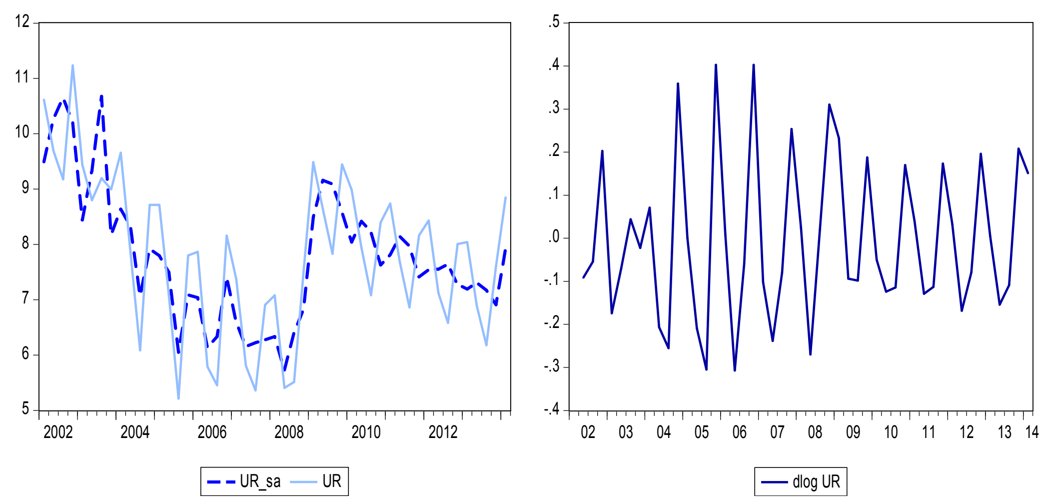
Nevertheless, despite the negative effects which are connected with a reduction in the number of working-age population and rising of unemployment rate, in the same period in Ukraine can be observed increase in economic activity of population and increase of the labor force participate rate (LFPR), as a result the labor force does not show such significant shifts (Fig. 1b) which are inherent in the general population aged 15 to 70 years. The main driver of economic development are social groups that have qualifications and employment opportunities, social activity and mobility, ability to adapt to existing conditions and effectively implement their abilities [8], and another driver is an increasing of economic activity of «third age» people [9].

The behavior of a UR series, which according to the ILO defines unemployment rate in Ukraine and a LFPR series, which determines the percentage of the working age population, which is a part of the labor force and dynamics of seasonally adjusted (using multiplicative moving average method) values are depicted in Fig. 2a and 3a respectively. Figs. 2b and 3b depicts their quarterly growth rates.




**(a)** **(b)**

**Fig. 1. Dynamics in the number of working age population and labor force during 2002—2014**
*Source: Data of the State statistics service of Ukraine [10], elaborations of the author*




**(a)** **(b)**

**Fig. 2. Dynamics of a) unemployment rate (ILO) (series UR) and b) its growth rate over the 2002—2014**
*Source: Data of the State statistics service of Ukraine [10], elaborations of the author*

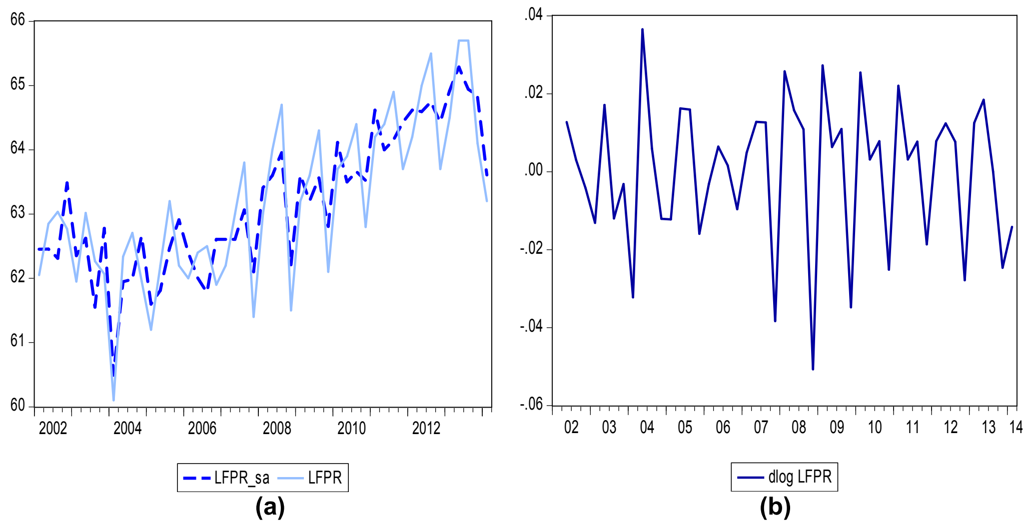



**Fig. 3. Dynamics of a) percent of economic activity of population (series LFPR) and b) its growth rate over the 2002—2014**

*Source: Data of the State statistics service of Ukraine [10], elaborations of the author*

J. Emerson, M. Kakinaka and H. Miyamoto, D. Liu as well as many other scientists conducted an analysis of the relationship between economic activity of population and unemployment rate over different periods of the business cycle in different countries [11–13]. Their results show that the relationship between unemployment rate and LFPR is caused by influence of factors that often have opposite characters of the impact, and depends on a number of different circumstances and state of the labor market and therefore scientists received controversial conclusions. In the results of researches in [14–16] shown that during recession an unemployment rate only partially presents real situation on the labor market and therefore during periods of recession an attention to the analysis and modeling of LFPR should be paid. One of the reasons is connected with effect of discouragement of workers in crisis periods because they are not even included in the labor force and do not affect the unemployment rate [17,18]. As consequence during periods when economic activity decreases and the economy is in recession, emerge the number of workers that are leaving the labor force and a dynamic asymmetry in the levels of employment and unemployment can be observed [19]. Nevertheless at the same time along with the outflow of discouraged workers in order to prevent a reduction of their income households can increase their labor supply. In the result there could be an influx of new workers, particularly young people and elderly people, consequently the labor market equilibrium can be maintained. The coefficient of participation in the labor force does not undergo significant changes or even increases.

Therefore the researchers emphasize that due to two effects such as outflow of discouraged workers and an inflow of additional employees during periods when economic activity declines LFPR can be more effective indicator of the labor market compared with the levels of employment and unemployment. In this regard, in order to deepen the analysis of the current state of the labor market in Ukraine, considering the complicated demographic and economic situation in the country a study of dynamics of population economic activity is relevant and necessary.

The purpose of this article is the empirical analysis and econometric modeling of nonlinear and asymmetric dynamic behavior of the labor force participation rate that will enable to evaluate the tension and tightness of the domestic labor market, and identify the necessary policy measures in social and labor sphere.

## 2.2 Empirical Analysis

Modelling is conducted for time series *LFPR*, which measures the labor force participant rate (in %) in Ukrainian labor market and it can be calculated by the formula:

*LFPR* = 100%* (*EMPL* + *UNEMPL*) / *WAP*,

where

*EMPL* – The number of employed in the economy of Ukraine (thous. people);

*UNEMPL* – The number of unemployed in Ukraine (thous. people);

*EMPL* + *UNEMPL* = *LF* – labor force in Ukraine (thous. people);

*WAP* – the number of working-age population in Ukraine (thous. people).

Unemployment rate is determined by the formula

*UR* = *UNEMPL* / *LF*.

Reasonable application of econometric techniques in order to build an adequate model to describe the behavior of percent of economic activity in Ukraine requires a preliminary statistical analysis of time series *LFPR* properties, in particular, this includes research of stationary. It should be noted that in different countries series that determines the percentage of working age population participating in the labor force is characterized by different statistical properties. In particular in [14] M. Gustavsson and P. Österholm shown that the *LFPR* in Australia, Canada and the United States are not stationary. In [20] the authors after conducting the analysis of general *LFPR* and *LFPR* for men and women separately received confirmation that structural changes in the economy may interfere stationarity. Scientists claim that if *LFPR* is stationary, the unemployment rate in the long run is transformed into employment. If the *LFPR* shows nonstationarity property the unemployment rate is not a good indicator of joblessness on the labor market [16].

Results of the study of *LFPR* series stationarity in Ukraine on the basis of augmented Dickey-Fuller unit root test are presented in Table 1. The test shows that the series is nonstationary, and therefore labor supply response to macroeconomic shocks may vary depending on job prospects.

Whereas according to a research $LFPR_t$ series is integrated of first order, and a series of first differences of his natural logarithms, which determine the growth rate of the economic active population share is stationary (Table 1), the modeling has to be performed for a Δ log *LFPR* series:

$$\Delta \log LFPR_t = \log LFPR_t - \log LFPR_{t-1},$$

Which determine the first differences of natural logarithms of times series $LFPR_t$.

Behavior and previously conducted econometric analysis of domestic *LFPR* show its asymmetry. In particular, it was found that the rate of growth percent of economically active population responds differently to positive and negative shocks. Negative disturbances have a larger and longer impact on the change in percent of economic activity than positive [21]. Detected asymmetry in the responses requires a nonlinear econometric analysis and application of modern models of time series in modeling the economic activity in the labor market. Should be noted that the need for nonlinear models often occurs in the macroeconomic and financial modeling [22]. Although for modeling of macroeconomic processes to describe nonlinear economic phenomena researchers often use a linear approximation, but in many cases series characteristics require the use of nonlinear specifications. Nonlinear econometric models can be divided into two broad categories. The first category includes model that does not contain a linear model as a special case, and the second category includes a number of popular models, which generalize linear models and under certain restrictions are converted into linear.

**Table 1. Testing of nonstationarity character of the labor force participant rate**

| Exogenous variable | ADF-statistics | Significant level | Critical values | *p*-value |
|---|---|---|---|---|
| **The null hypothesis: log *LFPR* contains unit root** | | | | |
| Intercept**,** linear trend | -3,277571 | 0,01<br>0,05<br>0,10 | -4,180911<br>-3,515523<br>-3,188259 | 0,0834 |
| **The null hypothesis: Δ log *LFPR* contains unit root** | | | | |
| intercept | -14,89231 | 0,01<br>0,05<br>0,10 | -3,588509<br>-2,929734<br>-2,603064 | 0,0000 |

*Source: Evaluations of the author*

Switching regression models, various Markov switching models and smooth transition regression models are examples of models belonging to this class [22,23].

### 2.3 Method

In the result of conducted econometric analysis and taking into account the experience of foreign studies [23,15] for modeling an economic activity in Ukraine was selected a smooth transition regression model (STR model). The STR model is a nonlinear regression model, which can be regarded as an extension of switching regression model. In addition, Smooth transition autoregressive regression (STAR) has the advantage in usage compared to the threshold autoregressive model by giving a possibility to take into consideration smooth transition between different modes.

A smooth transition regression model (STR model) has the following general form [24]:

$$y_t = \varphi' z_t + \theta' z_t G(s_t; \gamma, \alpha) + u_t$$
$$=(\varphi + \theta G(s_t; \gamma, \alpha))' z_t + u_t , \quad t=1,\dots,T, \quad (1)$$

where $z_t = (w_t', x_t')'$ – vector of explanatory variables, $w_t' = ( 1, y_{t-1}, \dots , y_{t-p} )'$ , $x_t' = ( x_{1t}, \dots , x_{kt} )'$ – vectors of exogenous variables, $\varphi = (\varphi_0, \varphi_1,\dots, \varphi_m)'$ i $\theta = (\theta_0, \theta_1,\dots, \theta_m)'$ – $(m+1)$-dimensional vectors of unknown parameters ($m = p + k$), $u_t \sim iid\ (0, \sigma^2)$ sequence of random disturbances. Transition function $G(s_t; \gamma, \alpha)$ is defined as a continuous restricted function of continuous transition variable $s_t$, slope parameter $\gamma$ and vector of location parameters $\alpha = (\alpha_1,\dots, \alpha_K)'$, $\alpha_1 < \dots < \alpha_K$. Representation (1) shows that the model can be interpreted as a linear model with stochastic and time changing coefficients whose values are set by function $\varphi + \theta G(s_t; \gamma, \alpha)$. Should be noted that values of location parameters increases with $k$ growth, and slope parameter is assumed to be positive.

The first part of the model (1) characterizes the linear component of the system with parameters $\varphi_j$ ($j=1,\dots,m$), while the second part $\theta' z_t G(s_t; \gamma, \alpha)$ describes non-linear component with parameters $\theta_j$. If the model (1) does not contain exogenous variables vector $z_t = (1, y_{t-1}, \dots, y_{t-p})$ consists only of constant and lags of endogenous variable, the transition variable is defined as $s_t = y_{t-d}$ or $s_t = \Delta y_{t-d}$, $d > 0$, and vectors of parameters $\varphi$ and $\theta$ contains $p+1$ coefficients, including intercept and $p$ slope coefficients at lagged values, then the model (1) is one-dimensional smooth transition autoregressive model.

If the transition function that determines the behavior of non-linear part in (1), is given by the logistic function.

$$G(s_t; \gamma, \alpha) = 1 / (1 - \exp ( - \gamma \prod_{k=1}^{K} (s_t - \alpha_k) ) )$$
$$\gamma > 0, \quad (2)$$

Then we receive a logistic smooth transition regression model. In practical modeling are usually used values $K = 1$ and $K = 2$, and the appropriate models are indicated LSTR1 and LSTR2 [24]. For $K = 1$ model parameters $\varphi + \theta G(s_t; \gamma, \alpha)$ monotonously change with change of $s_t$ from $\varphi$ to $\varphi + \theta$. For $K = 2$ parameters are symmetric functions around the midpoint $(\alpha_1 + \alpha_2)/2$, in which the logistic function reaches its minimum value, which is contained between zero and 1/2. In this case, the transition function goes to zero when $\gamma\to\infty$ and is equal to 1/2, if $\alpha_1 = \alpha_2$ and $\gamma < \infty$. Parameter $\gamma$ defines the slope and $\alpha_1$, $\alpha_2$ – allocation of transition function values.

An alternative to LSTR2 model is an exponential STR (ESTR) model where the transition function has the form

$$G_E (s_t; \gamma, \alpha) = 1 - \exp ( -\gamma (s_t - \alpha^*)^2 ) , \quad \gamma > 0.$$

This function is symmetric around $s_t = \alpha^*$ and has at low and moderate values of the slope parameter $\gamma$ about the same shape but different minimum value (zero) comparing with the logistic function (2).

In practice the transition variable $s_t$ is usually stochastic and often is a part of vector $z_t$. It can be a linear combination of several variables and can measure the differences of some element $z_t$. If $s_t = t$ then we obtain a linear model with deterministically changing parameters.

The next step is conduction of one-dimensional econometric studies of series labor force participant rate *LFPR*, using method of LSTAR modeling. The order of the lags length included into the model are chosen on the basis of comparison of Akaike, Schwarz and Hannan-Quinn statistical criteria for the corresponding linear models. In order to account the seasonality in the series behavior in the model are included constant and seasonal variables *S1*, *S2*, *S3* which are taking the value 1 respectively in the first, second and third quarters and zero for all other quarters. Evaluation results of autoregressive models with different lags length show that the best choice is a model which includes three previous delay ($p=3$).

To justify the correctness of using a nonlinear smooth transition model (1) - (2) can be used a common methodology for testing the null hypothesis of linearity for the alternative of LSTR-nonlinearity. In case of STR model should be used an approximation of function transition (2) by its third-order Taylor expansion around the null hypothesis γ = 0. As a result for testing the following auxiliary regression is estimated [25]

$$y_t = \beta_0' z_t + \sum_{j=1}^{3} \beta_j' z_t^* s_t^j + u_t\ ,\quad t=1, \ldots, T, \quad (3)$$

where $z_t = (1,\ z_t^*)'$, $z_t^*$– $m$-dimensional vector, $u_t^* = u_t + R_3(s_t,\gamma,\alpha)\ \theta' z_t$, $R_3(s_t,\gamma,\alpha)$ – remainder of approximation, and parameters $\beta_j$ ($j=1,\ 2,\ 3$) can be represented as $\gamma\ b_j$, where $b_j$ are functions from $\theta$ and $\alpha$, $b_j \neq 0$. The null hypothesis of linearity is formulated as follows $H_0$: $\beta_1 = \beta_2 = \beta_3 = 0$, and is the usual linear hypothesis in the linear model. For the correct null hypothesis a test statistic has an asymptotic $\chi^2$ - distribution with three degrees of freedom. However, for small and medium-sized samples $\chi^2$- distribution statistics can be seriously distorted that is why in these cases it is recommended to use the appropriate F - statistic [25]. For the null hypothesis its distribution is approximated with $F[3,\ T–4m–1]$ Fisher distribution.

## 3. RESULTS

To determine the appropriate LSTR specifications for labor force participant rate will be chosen the set of potential transition variables $S=\{Trend,\ \Delta\log\ LFPR_{t-1},\ \Delta\log\ LFPR_{t-2},\ \Delta\log\ LFPR_{t-3}\ \}$ and conduct testing of nonlinearity in turn using each element of S as a transition variable. If the null hypothesis rejected for several transition variables then should be choosen one variable for which p - value of a test is the least. However, if several small p - values are close to each other it is necessary to extend the modeling and estimate more appropriate STR models and on the evaluation stage make a choice between them.

For selecting type of appropriate LSTR models the following sequence of tests is used: 1) testing the null hypothesis $H_{04}$ : $\beta_3 = 0$ (statistics $F4$); 2) testing the null hypothesis $H_{03}$ : $\beta_2 = 0$ on condition that $\beta_3 = 0$ (statistics $F3$) and 3) testing the null hypothesis $H_{02}$ : $\beta_1 = 0$ on condition that $\beta_3 = \beta_2 = 0$ (statistics $F2$). Should be noted that in particular case $\alpha = 0$ for model LSTR1 $\beta_2 = 0$, while for the models LSTR2 i ESTR $\beta_1 = \beta_3 = 0$ [24]. If $\alpha \neq 0$, still the $\beta_2$ is closer to the zero vector than $\beta_1$ or $\beta_3$ for model LSTR1, and vice versa for the model LSTR2. Therefore, if p-value of the test rejects the hypothesis $H_{03}$ one should choose a model LSTR2 or ESTR. Otherwise, a model LSTR1 should be chosen.

The results of conducted consecutive tests for different transition variables are shown in Table 2.

Tests show that adequate may be considered the LSTR1 model with transition variable $\Delta$ log $LFPR_{t-1}$ or $\Delta$ log $LFPR_{t-2}$ and LSRT2 model with transition variable *Trend*. LSTR1 model allows to model the behavior of asymmetric economic activity in the labor market and allows to describe dependence of the process properties on the phase of the business cycle in which the economy is, taking into account that the transition from one regime to another is smooth. Model LSTR2 is given a preference in case of usage trend variable as a transition variable, indicating that the dynamic nature of the process is similar for large and small values, but different in the middle. In particular by using LSTR2 nonlinear model it is possible to describe nonlinear short-term adjustments to equilibrium when the force of gravity to equilibrium trajectories is a non-linear function that depends on the deviation from equilibrium relationship.

However, estimation of the initial values of the parameters $\alpha$ and $\gamma$, and further evaluation and diagnosis of different smooth transition models discover that LSTR1 model with transition variable $\Delta$ log $LFPR_{t-1}$ is the best to describe the rate of growth of the economically active population share. Fig. 4 shows the residual sum of squares (SSR) as functions of the two parameters $\alpha$ and $\gamma$ for this model. In particular, Fig. 4a shows a surface-SSR and therefore determines its maximum, and Fig. 4b – level lines of SSR function, which make it possible to determine the minimum of residual squares sum.

Therefore, the final LSTAR model for the labor force participant rate in Ukraine is the following:

$$\Delta \log LFPR_t = \varphi_0 + \beta_1 S1_t + \beta_2 S2_t + \beta_3 S3_t + \varphi_1 \Delta \log LFPR_{t-1} + \varphi_2 \Delta \log LFPR_{t-2} + \varphi_3 \Delta \log LFPR_{t-3} + G(s_t;\gamma,\alpha)\ (\theta_1 \Delta \log LFPR_{t-1} + \theta_2 \Delta \log LFPR_{t-2} + \theta_3 \Delta \log LFPR_{t-3}) + u_t, \quad (4)$$

$$G(\Delta \log LFPR_{t-1};\gamma,\alpha)=1/(1+\exp(-\gamma(\Delta \log LFPR_{t-1}-\alpha)) \quad (5)$$

where $u_t \sim iid\ (0,\ \sigma^2)$, $s_t = \Delta \log LFPR_{t-1}$, $G$ – limited to zero and one transition function. Should be noted that linear autoregressive model is obtained when $\gamma = 0$. If $\gamma \rightarrow \infty$ we get $G\ (z_t;\ \gamma,\ \alpha) = 0$ for $\Delta \log LFPR_{t-1} < \alpha$ and $G\ (z_t;\ \gamma,\ \alpha) = 1$ for $\Delta \log LFPR_{t-1} > \alpha$. Transition function (5) is monotonically increasing with $s_t$. Slope parameter $\gamma$ describes how quickly the transition of function values goes from 0 to 1 and the parameter of distribution α determines where the transition occurs. The model describes a situation in which the phase of expansions and recession in the business cycle have different dynamics, with smooth transition between them. Slope parameter γ characterizes the rate of transition from one regime to another.

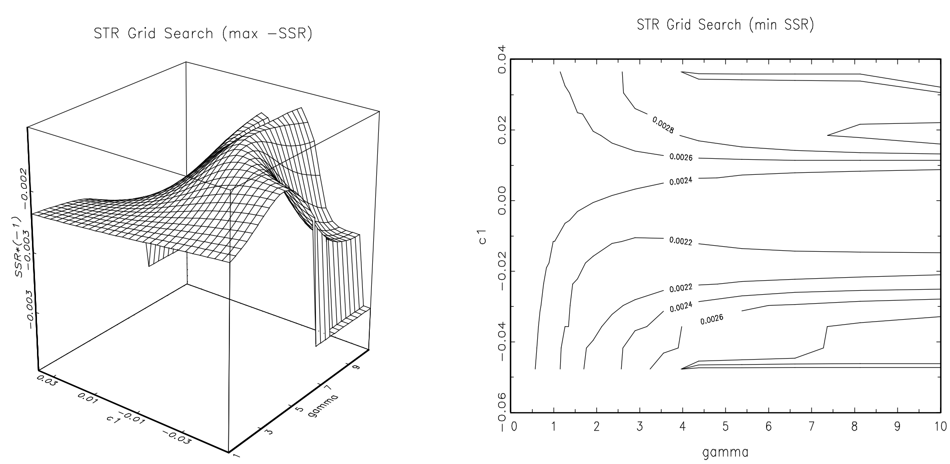
The results of parameter estimation of LSTR1 model with variable transition $\Delta \log LFPR_{t-1}$ and taking into account seasonal variables shown in Table 3. Estimation of nonlinear model is based on the maximization of conditional likelihood using an algorithm of Newton-Raphson. Convergence is achieved after 17 iterations.

Estimated value of the distribution parameter $\alpha = -0.01938$ determines the value at which may occur smooth changes in the dynamic behavior of economic activity of population from the periods of low growth rates to periods of high values. Modeling shows that the current rate of these changes responds differently to changes in the previous characteristics. The amplitude of previous fluctuations of rate of the labor force participation coefficient determines its smooth transition from low to high values. The estimated slope parameter $\gamma = 3.49$ characterizes the smoothness of this transition and the curvature degree of the transition function (5). Its rather high value shows that the economic activity of population quickly reacts to changes taking place in the labor market (Fig. 5).

**Table 2. Test results of autoregressive linearity**

| Transition variable | *p*-value *F* ($H_0$) | *p*-value *F4* ($H_{04}$) | *p*-value *F3* ($H_{03}$) | *p*-value *F2* ($H_{02}$) | Adequate model |
|---|---|---|---|---|---|
| *Trend* | 0,0356** | 0,0945 | 0,0312** | 0,5276 | LSTR2 |
| *Δ* log *LFPR(-1)* | 0,0482** | 0,9923 | 0,0427** | 0,0212** | LSTR1 |
| *Δ* log *LFPR(-2)* | 0,0136** | 0,0708 | 0,9221 | 0,0030*** | LSTR1 |
| *Δ* log *LFPR(-3)* | 0,7895 | 0,5624 | 0,5951 | 0,6839 | Linear |

*Note: ** denotes statistical significance at 5%, *** –at 1%*
*Source: Evaluations of the author*




(a) (b)

**Fig. 4. Graphic representation of residual sum of squares as a function of the slope and allocation parameters**
*Source: Evaluations of the author*

**Table 3. Estimation results of LSTR1 model for labor force participation rate**

| Variable | Linear part of LSTAR model | | Non-linear part of LSTAR model | |
|---|---|---|---|---|
| | **Coefficient** | ***t*-statistics (*p*-value)** | **Coefficient** | ***t*-statistics (*p*-value)** |
| *Const* | -0.0022 | -0.1012 (0.9200) | 0.01354 | -0.5666 (0.5749) |
| *S1* | 0.0056 | 0.8753 (0.3880) | — | — |
| *S2* | 0.0280 | 4.1089 (0.0003) | — | — |
| *S3* | 0.0194 | 3.3998 (0.0018) | — | — |
| *Δ* log *LFPR(-1)* | -0.2232 | -0.3525 (0.7268) | 0.19116 | -0.3179 (0.7526) |
| *Δ* log *LFPR(-2)* | 0.2282 | 2.0112 (0.0451) | -0.54341 | -2.2655 (0.0304) |
| *Δ* log *LFPR(-3)* | -0.8898 | -1.6784 (0.1030) | 0.44527 | 0.7986 (0.4304) |
| Parameters of transition function | | | | |
| *Γ* | — | — | 3.49793 | 2.2352 (0.0257) |
| *A* | — | — | -0.01938 | -2.9427 (0.0060) |

*Source: Estimations of the author*

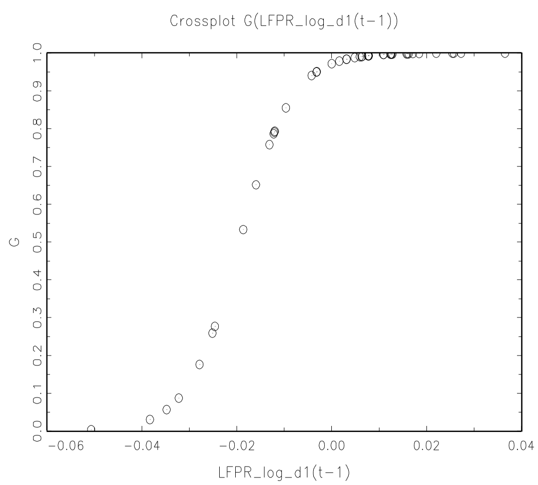



**Fig. 5. Plot of estimated transition function**
*Source: Evaluations of the author*

Comparison of modeling results based on linear AR(3) model and developed nonlinear model (4)–(5) shows a significant reduction of information criteria and standard error of the model, as well as increasing coefficient of determination, confirming the need for application of nonlinear modeling approaches.

There is a need to verify the adequacy modeling of nonlinearity originally found in the data and to test the presence of an additional nonlinearity, which could still remain. To carry out such checks should be considered the following additive STR model [24]:

$$y_t = \varphi' z_t + \theta' z_t G(s_{1t}; \gamma_1, \alpha_1) + \psi' z_t H(s_{2t}; \gamma_2, \alpha_2) + u_t , \quad (6)$$

where $H(s_{2t}; \gamma_2, \alpha_2)$ is another transition function which has the following form (2), a $u_t \sim$ iid $N[0,\sigma^2]$.

The null hypothesis of no additional nonlinearity is formulated as $H_0$: $\gamma_2 = 0$ for (6).

Application of LM-type test to check this hypothesis is similar to the testing of initial nonlinearity. The difference that arises here in comparison with the case of testing the linearity in the initial model is that in this case the vector $z_t$ in (3) is replaced by a gradient vector $v_t = (z_t', z_t' G(s_{1t}; \gamma_1\hat{}, \alpha_1\hat{}), g_t(\gamma\hat{}), g_t(\alpha_1\hat{})')'$ , where $g_t(\gamma) = \partial G(s_{1t}; \gamma_1, \alpha_1)/\partial\gamma_1|_{(\gamma 1, \alpha 1)=(\gamma 1\hat{}, \alpha 1\hat{})}$ and $g_t(\alpha_1) = \partial G(s_{1t}; \gamma_1, \alpha_1)/\partial\alpha_1|_{(\gamma 1, \alpha 1)=(\gamma 1\hat{}, \alpha 1\hat{})}$ .

Besides testing the residual nonlinearity to justify the adequacy of the constructed model the parameters stability of evaluated model (4)–(5) also should be checked. For testing the regression (1) is rewritten as [24,25]

$$y_t = \varphi(t)' z_t + \theta(t)' z_t G(s_t; \gamma, \alpha) + u_t , \quad \gamma > 0 \quad (7)$$

where

$$\varphi(t) = \varphi + \lambda_\varphi H_\varphi (t^*; \gamma_\varphi, \alpha_\varphi) \text{ and } \theta(t) = \theta + \lambda_\theta H_\theta (t^*; \gamma_\theta, \alpha_\theta), \quad (8)$$

where $t^* = t/T$ and $u_t \sim$ iid $N[0,\sigma^2]$. Functions $H_\varphi (t^*; \gamma_\varphi, \alpha_\varphi,)$ and $H_\theta (t^*; \gamma_\theta, \alpha_\theta)$ are determined in (8) for $s_t = t^*$. They characterize two different time varying vectors of parameters whose values vary smoothly between $\varphi$ and $\varphi + \lambda_\varphi$ and $\theta$ and $\theta + \lambda_\theta$ respectively. Equations (7)–(8) define a time-varying smooth transition regression model. The null hypothesis of parameter constancy is formulated as $H_0$: $\gamma_\varphi = \gamma_\theta = 0$, while the alternative hypothesis defines a smooth change of parameters in time and has the form or $H_1$: $\gamma_\varphi > 0$, or $H_1$: $\gamma_\theta > 0$, or combines these alternatives.

For testing the null hypothesis we use the LM-type test. In this case should be constructed an auxiliary regression of residual $u_t$ concerning.

$$v_t = [z'_t,\ z'_t\, t^*,\ z'_t(t^*)^2,\ z'_t(t^*)^3,\ z'_t\, t^*\, G(s_t;\ \gamma,\ \alpha),\ z'_t(t^*)^2\, G(s_t;\ \gamma,\ \alpha),\ z'_t\,(t^*)^3\, G(s_t;\ \gamma,\ \alpha)]'.$$

Since $v_t$ is a $(7(m+1)\times 1)$-dimensional vector and the $\chi^2$-statistics degree of freedom is equal to $6(m + 1)$, it is recommended to use F-version of the test. The results of testing the residual non-linearity and stability of the model parameters are shown in Table 4.

Conducted testing indicates the stability of the model parameters and absence of additional nonlinearity and therefore confirms the adequacy of choosing LSTAR1 model to describe the dynamics of a percent of the economically active population in Ukraine.

Also it is necessary to conduct the diagnostics of the constructed model (4)–(5) based on the study of the properties of its residuals, graphic images of which are shown in Fig. 6.

Testing the presence of some autocorrelation in residuals of STR models is a particular case of general test. In particular, testing the null hypothesis of no autocorrelation of model residuals (4)–(5) against the alternative of autocorrelation of order not greater than $q$ based on the regression of LSTAR evaluated model residuals $(\hat{u})_t$ of regarding its lagged values $(\hat{u})_{t-1}$, … , $(\hat{u})_{t-q}$ and partial derivatives of logarithmic likelihood function for the model parameters which are calculated at the point $\psi = \psi^*$, which maximizes log $L$. The test statistic has the following form [24]

$$F_{LM} = \{(SSR_0 - SSR_1)/q\} / \{SSR_1/(T-n-q)\},$$

where $n$ –number of model parameters, $SSR_0$ – sum of LSTAR model residuals squares and $SSR_1$ –sum of corresponding auxiliary regression residuals squares. For the null hypothesis the distribution of test statistic is approximated by Fisher distribution with $N_1 = q$ i $N_2 = T-n-q$ degrees of freedom.

Test results of residuals autocorrelation for model (4)–(5) for different lags orders that are shown in Table 5, confirm their non-autocorellation.

To diagnose the adequacy of evaluated model also the null hypothesis of absence of ARCH effects in the residuals should be checked and the normality of their distribution should be tested on the basis of Jarque–Bera test.

The results of the tests that are given in Table 6 indicate the normal distribution of residuals and absence of conditional heteroskedasticity.

Thus, the results of statistical tests show the correctness of conducted modeling and adequacy of smooth transition nonlinear logistic model for description of dynamic changes in the population economic activity in the labor market of Ukraine.

**Table 4. The results of testing the adequacy of model specification**

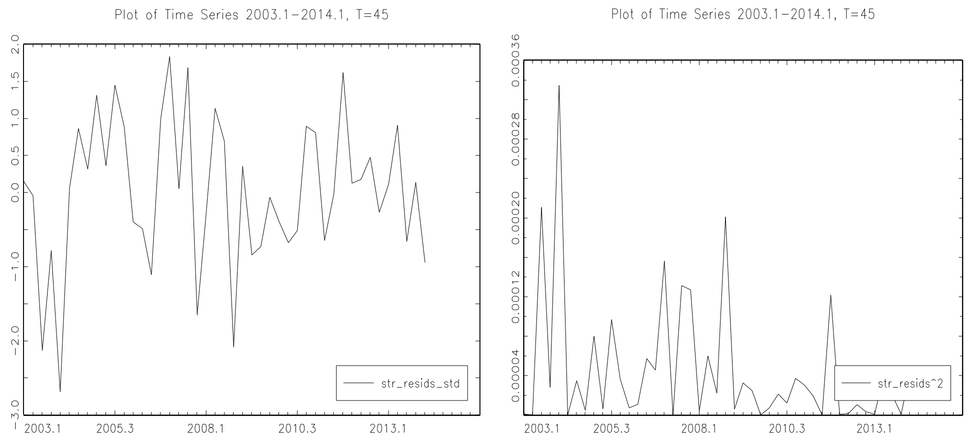
| **Test of no additive nonlinearity** | ***p*-value *F*** | ***p*- value *F4*** | ***p*- value *F3*** | ***p*- value *F2*** |
|---|---|---|---|---|
| | 0,63649 | 0,39900 | 0,95342 | 0,27155 |
| **Test of parameter constancy** | **Transition function** | **Test statistic** | **Distribution** | ***p*- value** |
| | $H_\varphi$ | 1,1917 | F[11,19] | 0,3549 |
| | $H_\theta$ | 1,2048 | F[22,8] | 0,4142 |

*Source: Evaluations of the author*

**Table 5. Test results of autocorrelation of LSTAR model residuals**

| | **Lags order** | **Test statistic** | **Distribution** | ***p*-value** |
|---|---|---|---|---|
| **LM-test of autocorrelation** | 1 | 0.7353 | F[1,30] | 0.3980 |
| | 2 | 0.3680 | F[1,28] | 0.6954 |
| | 3 | 0.5199 | F[1,26] | 0.6723 |
| | 4 | 0.7041 | F[1,24] | 0.5969 |
| | 5 | 0.5264 | F[1,22] | 0.7538 |
| | 6 | 0.4824 | F[1,20] | 0.8136 |
| | 7 | 0.6239 | F[1,18] | 0.7299 |
| | 8 | 0.5728 | F[1,16] | 0.7854 |

*Source: Evaluations of the author*




(a) (b)

**Fig. 6. Plot of standardized residuals and residuals squares of LSTR1 model**
*Source: Evaluations of the author*

**Table 6. The results of testing the normality residuals and ARCH-effects in LSTAR model**

| **ARCH-LM test (8 lags)** | **$\chi^2$ - statistics** | ***p* - value** | ***F* - statistics** | ***p* – value** |
|---|---|---|---|---|
| | 3.4271 | 0.9048 | 0.4721 | 0.8653 |
| **Normality test** | **Skewness** | **Kurtosis** | **Jarque–Bera statistics** | ***p* – value** |
| | -0.4604 | 3.1742 | 1.6468 | 0.4389 |

*Source: Evaluations of the author*

## 4. DISCUSSION

Demographic problems in Ukraine which are expected in the near future in the absence of timely and reasonable measures aimed at increasing labor productivity and labor force participant rate may have fundamental threats to the labor market. In particular, reducing the number of working-age people can cause a serious pressure on Ukrainian companies and thus make keeping the trajectory of economic growth an extremely difficult task. The current labor force participant rate and slow productivity growth do not allow to ensure the stability of social security and pension system and therefore the risk of extreme poverty remains and it is a particularly acute problem for the elderly population. In Ukraine are rather possible financial difficulties related to the increase in tax rates for those who work and whose contributions are involved in financial assistance for the elderly whose number is growing.

As a result, it is necessary to expand the tax base and promote the transfer of workers from the informal employment into the formal economy in order to avoid considerable costs for labor and double load on formally employed. Creation of more workplaces and improvement in their quality through capital investment and innovation will boost labor productivity and reduce the outflow of labor force abroad that will help to weaken negative impact of population aging on the economy. Considering that the hardest load will fall on the younger generation their level of education and training play a crucial role not only in their personal well-being in the future, but in the long term in labor productivity growth in Ukraine.

The impact of population aging on the economy and living standards can also be alleviated by increasing labor force participant rate and the employment rate of people who are poorly involved in the labor market or inactive and are not included in labor force, specifically young people, elderly, women, disabled, ethnic minorities and immigrants.

## 5. CONCLUSION

Timely and reasonable measures designed to further improve productivity and percent of population economic activity can partly prevent threats to domestic labor market in the long term that are associated with the influence of negative demographic tendencies. The effectiveness of implementation of these measures requires the development of qualitative models that allow explaining and predicting trends in unemployment and active of the population participation in the labor force. Developed nonlinear logistic model enables to model an asymmetry in the behavior of economic activity of population in the labor market and allows describing various dynamic properties of the process during periods of expansion and recession. The results of modeling quantitatively characterize smooth changes in the behavior of the time series from periods of low growth rates to periods of high values. The estimated slope parameter γ which determines the transition smoothness shows that the economic activity of population quickly reacts to changes taking place in the labor market. In times of crisis Ukrainian households in order to prevent the decline of their revenues increase labor supply and at the same time youth and elderly people show increased activity in job search. Increase of labor force participation rate in the labor market will allow to promote production of domestic goods when properly stimulate job creation in line with forecasted market demands, ensuring efficient employment, assistance in employment, retraining and professional development of persons who are released as a result of changes in market conditions.

## COMPETING INTERESTS

Author has declared that no competing interests exist.

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