The book investigate the asymmetries properties and nonlinear structure of behavior for number of macroeconomic indicators that represent the socio-economic sphere. The empirical study include the econometric modeling of processes on Ukrainian labor market. The research is based on threshold-disturbance moving average and threshold-disturbance autoregressive models that elicited a significant asymmetric reactions of labor force participant rate, unemployment rate and productivity to positive and negative macroeconomic shocks. For modelling the nonlinear dynamics, the logistic smooth transition autoregressive models is developed.

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Asymmetries and Nonlinearities in Socio-Economic Sphere

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ASYMMETRIES AND NONLINEARITIES IN SOCIO-ECONOMIC SPHERE

Monograph

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CONTENTS

INTRODUCTION

The current state of the socio – economic phere is often characterized by large disparities which are inherent for transitional and crisis periods of economic development. In particular, such asymmetries as institutional, economic, social and informational exist, with both positive and negative consequences. The existing significant discrepancies in the employment structure, wages and labor productivity, increased unemployment, uneven income distribution and social vulnerability of poor people show urgent problems in social and labour spheres that are caused by both internal and external factors, particularly for Ukraine.

Conclusions of researches of labor markets and economic fluctuations in the works of scientists from different countries demonstrate the importance of analyzing the dynamics of unemployment rate and labor force participation rate as for developed countries (D. Petrongolo, C. Pissarides, M. Elsby, B. Hobijn, A. Sahin, W. Zandewghe et al.), as for developing countries (O. Yuldashev, O. Khakimov, S. Verick, S. Cengiz, A. Sahin, A. Kolot et al.), as well as the correlation relationship between them (D. Dagsvik, T. Kornstad, T. Skjerpen, Y. Ozerkek, E. Papapetrou, D. Bakas et al.).

Socio-economic phere as well as unemployment rate and economic activity depend on many factors. As well labor market indicators reactions to changes in these factors in various countries are different. Important determinants of long-term trends in labor supply are the demographic and educational situations. Changes in the age structure of the population have a significant impact on the dynamics of processes in the labor markets of European countries (Biagi and Lucifora, 2008). Researches of differences in economic activity and unemployment rates among European countries demonstrate the importance of age and cohort effects which determine changes in social norms and preferences for participation in the labor market (Balleer, Gomez-Salvador and Turunen, 2014) and significant long-term dependencies between unemployment rate and macroeconomic variables (GDP and inflation) particularly among young people (Caporale and Gil-alana, 2014).

Differences in overall economic activity and unemployment rate in various countries to a certain extent caused by differences in the economic activity of women, which is very different for developed countries (Ukil, 2015; Mishra and Smyth, 2010) and developing countries (Abdulloev et al., 2014; Naidu, 2016). In the meantime research of the hypothesis that the economic activity of women is characterized by U-curve and depends on the development of country (including structural changes, education, human capital development, dynamics of birth) do not give a definitive conclusions and empirical evidence (Gaddis and Klasen, 2014; Tam, 2011). In particular study of women economic activity based on two-step methodology of econometric exercise and general equilibrium modeling indicates the importance of specific barriers in some countries (Tsani et al., 2013). In developing countries significant differences in the economic activity of women are caused by wide variety of economic and social factors that include economic growth, education, social norms (Verick, 2014), furthermore important factors are international migration (Abdulloev et al., 2014) and historical unforeseen circumstances (Gaddis and Klasen, 2014).

However long-term (demographic) trends explain only part of the changes in the labor supply and the rest of the changes are caused by cyclical factors including recession (Zandweghe, 2012). Studies show that economic activity is pro-cyclical in the USA (Erceg and Levin, 2014) while in the euro area it is countercyclical (Nucci and Riggi, 2016).

During economic fluctuations it is important to study the relationships between economic activity and unemployment rate. Works of a number of scientists show that in European countries changes in labor force participation rate are related with changes in cyclical unemployment (Elsby et al., 2013; Petrongolo and Pissarides, 2008). However, direction and causality of this interrelation and correlation sign can be different and depend on the economic environment.

In particular, study of 40 OECD countries reveals that inflows of economic activity of a population is accompanied by increased unemployment rate, while the outflows of potential employees from the labor force and their transition to inactive status with a some lag causes a negative shift in the unemployment rate (Elsby et al., 2013). Meanwhile studies of the labor market in Greece which has undergone significant disturbances and is characterized by a medium level of economic activity and simultaneously the highest in Europe unemployment rate, based on the two-regime threshold cointegration model show that the LFPR was increasing in the period from 1990 to 2010 demonstrating the long-term trend and was not dependent of UR. However, after 2010 LFPR shows a strong negative dependence on UR which was high in this period and associated with the fall in employment rate (Papapetrou and Bakas, 2013). When a person decides to work or not they evaluate the expected benefits from job search and state of labor market and in the process a significant part of the unemployed become discouraged. In particular in European countries discouraged worker effect is rather high among women indicating the undervaluation of female unemployment (Ozerkek, 2013; Dagsvik, Kornstad and Skjerpen, 2013). At the same time high level of UR not always pushes from seeking job although new members of labor force have little chance for work.

Analysis and study of asymmetric and nonlinear behavior of labor market indicators for different countries are based on an investigation of econometric time series models (Acemoglu and Scott, 1994). In particular, Faria, Cuestas and Mourelle (2010) substantiated the causality direction and nonlinearity of the relation between unemployment and entrepreneurship and estimated STAR-EXT model for a set of OECD countries. Holmes and Silverstone (2006) used a nonlinear Markov regime-switching approach for modeling an asymmetry between unemployment and output in the United States in 1991 and 2001. Pérez, Rodríguez and Usabiaga (2003) detected a nonlinear and asymmetric nature of relationship between the output gap and the unemployment gap for Andalusia and Spain. Cancelo (2007) investigated the nonlinearities in the unemployment rates of six developed economies by using a smooth transition autoregression model where the transition variable is GDP growth and indicated that nonlinearities are induced by cyclical asymmetries. Hotchkiss and Robertson (2012) by using the standard labor-leisure choice model found that labor force participation decisions across demographic groups in response to changes in labor market conditions are asymmetric. Cengiz and Sahin (2014) evaluated smooth autoregressive transition models for Turkish labor force participation rates and showed a nonlinearity of behavior of participation rates for men and women.

CHAPTER 1

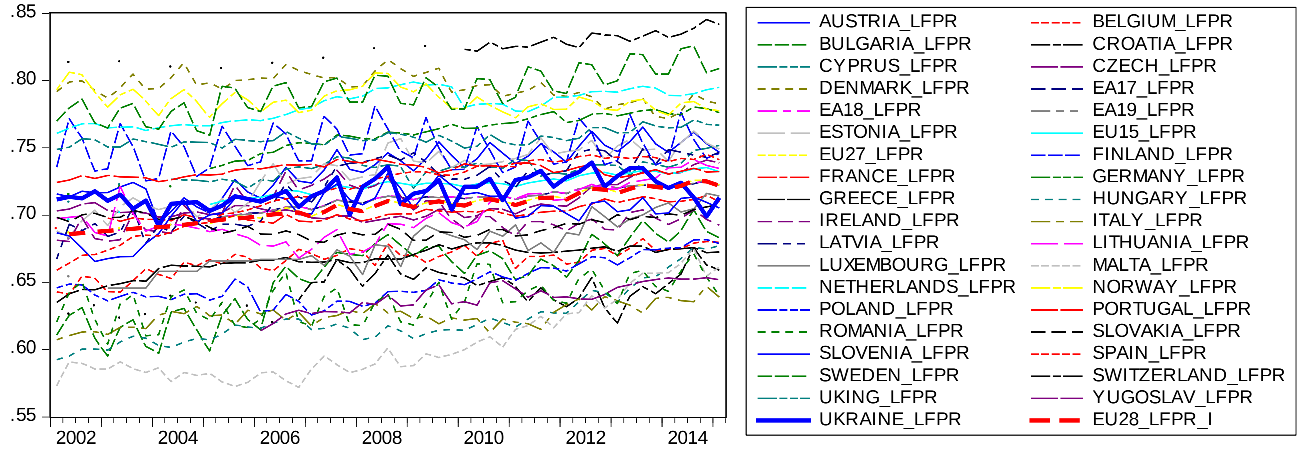
EVALUATION OF ASSYMETRIC EFFECTS IN DYNAMICS OF SOCIO-ECONOMIC INDICATORS

Analysis of Ukrainian labot market processes in comparison with European tendencies

We would like to focus on the analysis of processes on Ukrainian labot market as well as making comparison with EU countries labor markets. Over the last decade Ukraine is characterized by approximately the average European level of economic activity of population and similar dynamic properties with upward trend (Fig. 1). However, the dynamics of labor force participation rate demonstrates slightly different trend characteristics if compared to countries where this indicator is close to Ukrainian (Estonia, Latvia, Lithuania, Slovenia, Spain). Particularly in Ukraine economic activity is increasing considerably slower, especially in the post-crisis period since 2008 and is characterized by a significant decline during the 2014-2015. Such dynamics is caused by poor economic development of Ukraine and complicated political situation. Dynamics of unemployment rate in contrast to the labor force participation rate significantly different for various European countries (Fig. 2). Ukraine shows its own fluctuations. The unemployment rate in Ukraine has increased significantly since the crisis in 2008, although not as much as in Greece and Spain. Revolution that took place in Ukraine at the beginning of 2014 has led to a rapid increase in unemployment rate and falling an economic activity of the population, which due to military action in the east of the country and economic instability not returned to previous level.

Figure 1

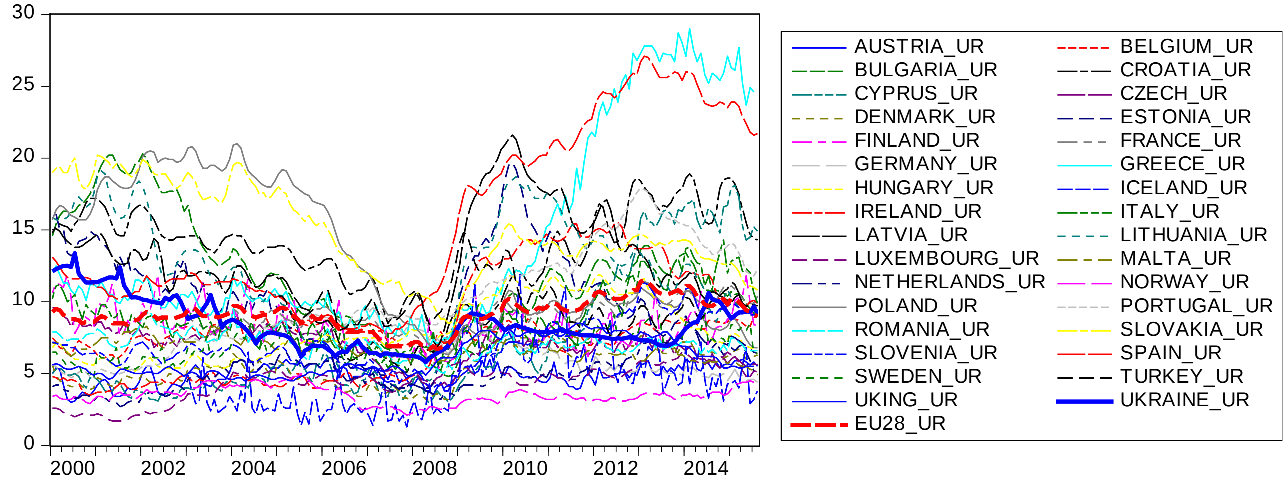
Dynamics of labor force participant rate (LFPR) in European countries



Source: data from EUROSTAT Database and State Statistics Service of Ukraine, elaborations of the author.

Figure 2

Dynamics of unemployment rate (UR) in European countries



Source: data from EUROSTAT Database and State Statistics Service of Ukraine, elaborations of the author.

Demographic trends in Ukraine are critical. During the last decades because of low birth rate, high mortality rate and emigration of people of working age in Ukraine occurs a sharp decrease of the population (12.5% in the last 20 years). Moreover similar to other European countries there is a significant aging of the population. Ukraine is classified as "old" nation. The proportion of the population whose age is older than 65 years is more than 15%, and the percentage of people aged over 60 years is about 22%.

Migration is also an important demographic factor that influences economic activity and unemployment rate (Tudorache, 2006). In Ukraine prevails workforce emigration mostly in Poland, Czech Republic, Italy, Portugal and Russia. However it is impossible to adequately measure the effect of such labor force leaving because of the lack of truthful data and due to the fact that such labor force flows are usually illegal.

Economic activity and unemployment rate are different in various regions of Ukraine while their dynamics depends on specifics of the region. Situation in Ukraine is similar to European countries where using the standard deviation, non-parametric kernel densities and stochastic kernels are determined two different periods, and detected strong polarization after the crisis (between 2007 and 2013) which applies to both countries and regions (Beyer and Stemmer, 2016).

In Ukraine, economic and social factors that include economic growth, education, social norms, international migration, historical unforeseen circumstances have a significant impact. Economic activity of women is significantly lower (about 10-15 percent) for the economic activity of men, particularly because household duties and responsibilities of caring for the children are laid mainly on women. This situation is encouraged by fairly high social payments after childbirth and is caused by limited access to high-quality services for caring for the children.

Apart from demographic and cyclical factors researchers demonstrate the importance of educational level and social welfare programs (Kennedy and Hedley, 2003), pay inequality, cohesion and competitiveness (Galbraith and Garcilazo, 2010), state of health of the nation (Cai, 2010) which unfortunately are currently not at a high level in Ukraine.

In Ukraine like in other European countries a desire to get additional job and additional income prevails "pessimistic attitudes" about the possibilities of the labor market. Since nominal wage is not flexible and inflation is high the real wage decreases. This leads to increased economic activity due to the effects of habits and consumer preferences which usually are strong (Blanchard, Gali, 2007). As in some European developing countries (Yuldashev and Khakimov, 2011; Senaj et al., 2016) economic activity in Ukraine is sensitive to changes in wages that arise from changes in income taxes and transfers but the elasticity of these changes is small.

At the present stage of development the Ukrainian labor market is characterized by asymmetry of natural, social and migratory reproduction of the population as well as spatial asymmetry of regional labor resources placement (Krasnonosova and Yermolenko, 2013); significant economy dependence on inconsistent political decisions, aging of production assets due to insufficient funding of the production sector (Lukyanenko and Semko, 2012); the limited effect of foreign direct investment and asymmetry in the distribution of productive forces (Maslov, 2012); underutilization of labour resources and not optimalemployment allocation (Kolot, 2012); inconsistency between professional and qualification structure of regional labor resources and needs of regional labor markets (Daradkeh et al., 2012). Moreover the labour market is also characterized by asymmetry in processes of adaptation to changing market conditions. In this regard, an important issue is the development and analysis of nonlinear economic and mathematical models which allow to identify the characteristics of asymmetric dynamics of the main macroeconomic indicators of the labor market and their reactions to positive and negative shocks that disturb the economic environment.

We conduct an empirical analysis and econometric modeling of behavior of the key labor market indicators to identify the characteristics of their asymmetric dynamics, improve the correctness of their forecasts and the effectiveness of conducting social and economic policies measures in conditions of economic instability in Ukraine. Statistical research will be performed on a basis of a quarterly data for years 2002—2017, obtained from statistical reports of Ukrainian State

Statistics. Namely, we will examine series: *UR* (unemployment rate, determined by the ILO, in %); *UROF* (registered unemployment rate, in %); *RR = 100 * UROF/UR* (the percentage of the unemployed registered in employment centers); *LFPR* (labour force participation rate (among the population aged 15-70 years), in %); *EMPL* (employed population in thousands persons); *PROD* (productivity, in thousands of UAH per person); *UNEMPL* (number of unemployed population in thousands persons); *UNEMPLOF* (number of officially registered unemployed persons in thousands persons). In Table 1 there are some of their statistical characteristics.

Analysis of population economic activity and unemployment rate as well as research of relationships among them during different periods of business cycle were a point of interest for many scientists all over the world. In particular, Kakinaka and Miyamoto (2012) estimated long-term cointegration relationships between LFPR and unemployment rate in Japan and they demonstrated that LFPR series can decrease because of discouraged worker effect during the periods of unemployment rate rising. Liu (2014) complemented the research for Japanese economy, considering the possibility of multiple structural breaks for panel data from a regional perspective. Emerson (2011) was modeling interrelation between labor force participation rate and UR for the USA historical data. Scientists state that high unemployment rate during recession can force people to refuse from job searching, because in such periods job searching costs may prevail over an employment benefits (Benati, 2001). As a result, a negative correlation between unemployment and economic activity can be observed, and therefore the unemployment rate may be a significant factor that negatively affects the decision of entering a labor force or not. However, other researches (Hernández and Orraca, 2009) show that at the same time (during economic recessions) households increase their job offer to prevent reduction of their income, and young workers demonstrate significant activity in job searching. In this regard, rise in unemployment may be accompanied by an increase in LFPR during business cycles, and in the long term prospect a relationship between the LFPR and unemployment may not be traced.

Table 1

Statistical Characteristics of Population Unemployment and Economic Activity Indicators

Period	Mean	Minimum	Maximum	Standard Deviation
Unemployment Rate (*UR*)				
2002—2004	9.12	6.08	11.23	1.29
2005—2008	6.69	5.21	8.71	1.16
2009—2013	7.91	6.17	9.48	0.92
2014—2017	9,32	8,16	10,59	0,63
Registered unemployment rate (*UROF*)				
2002—2004	3.70	3.40	4.00	0.15
2005—2008	3.08	2.40	3.90	0.39
2009—2013	2.56	1.80	4.40	0.62
2014—2017	2,4	1,7	3,00	0,35
Percentage of the unemployed registered in employment centers (*UROF/UR*)				
2002—2004	41.27	32.93	55.88	5.81
2005—2008	46.67	37.17	60.28	6.29
2009—2013	32.29	25.41	46.38	5.91
2014—2015	25,80	19,03	31,72	3,87
Labour force participation rate (*LFPR*)				
2002—2004	62.58	60.10	63.04	0.79
2005—2008	62.54	61.20	64.70	0.98
2009—2013	64.18	62.10	65.70	0.92
2014—2015	62,25	60,60	63,39	0,73

Source: data of the State Statistics Service of Ukraine, elaboration of the authors.

In Ukraine, instability of the labor market, caused by the instable development of national economy and its separate sectors, as well as typical seasonal fluctuations obstruct ensuring stable employment of working population. Conducted statistical analysis shows that a significant negative correlation for the entire period from 2002 to 2015 exists between unemployment rate and coefficient of labour force participation (Table 2). Also after 2009 inverse relationship between *UR* and *LFPR* strengthened. If by 2008 the correlation factor was about -0.5, then after 2009 it was almost -0.9, indicating that over time in Ukraine the increased unemployment is accompanied by a significant reduction of the labor force participation factor.

Table 2

The Correlation Coefficients among Labor Force Participation Rate, Unemployment Rate Defined by ILO and Registered Unemployment Rate

Period	Corr [*LFPR*, *UR*]	Corr [*LFPR*, *UROF*]	Corr [*UR*, *UROF*]
2002Q1 – 2008Q4	-0.4819 (p-value = 0.0094)	-0.4367 (p-value = 0.0201)	0.7847 (p-value = 0.0000)
2009Q1 – 2013Q4	-0.8690 (p-value = 0.0000)	-0.3195 (p-value = 0.1697)	0.6062 (p-value = 0.0046)
2014Q1 – 2017Q4	-0.9624 (p-value = 0.0087)	-0.0236 (p-value = 0.9700	0.0564 (p-value = 0.9282)

Source: elaborations of the authors.

The similar result is obtained by exploring the dynamic correlation based on estimating the distributed lag model

$$LFPR_t = \alpha_0 + \alpha_1 UR_t + \alpha_2 UR_{t-1} + \alpha_3 UR_{t-2} + \varepsilon_t$$

on the basis of samples for different periods (Table. 3)

Table 3

The Dynamic Correlation Coefficients among Labor Force Participation Rate and Unemployment Rate

Period	α_1	α_2	α_3
2002Q1 – 2008Q4	-0.3413	-0.0463	0.2025
	(p-value = 0.0082)	(p-value = 0.7387)	(p-value = 0.0958)
2009Q1 – 2013Q4	-1.1643	0.4050	-0.3987
	(p-value = 0.0000)	(p-value = 0.0002)	(p-value = 0.0002)
2014Q1 – 2017Q4	-1.0764	-0.1411	-0.0533
	(p-value = 0.0016)	(p-value = 0.3832)	(p-value = 0.6023)

Source: elaborations of the authors.

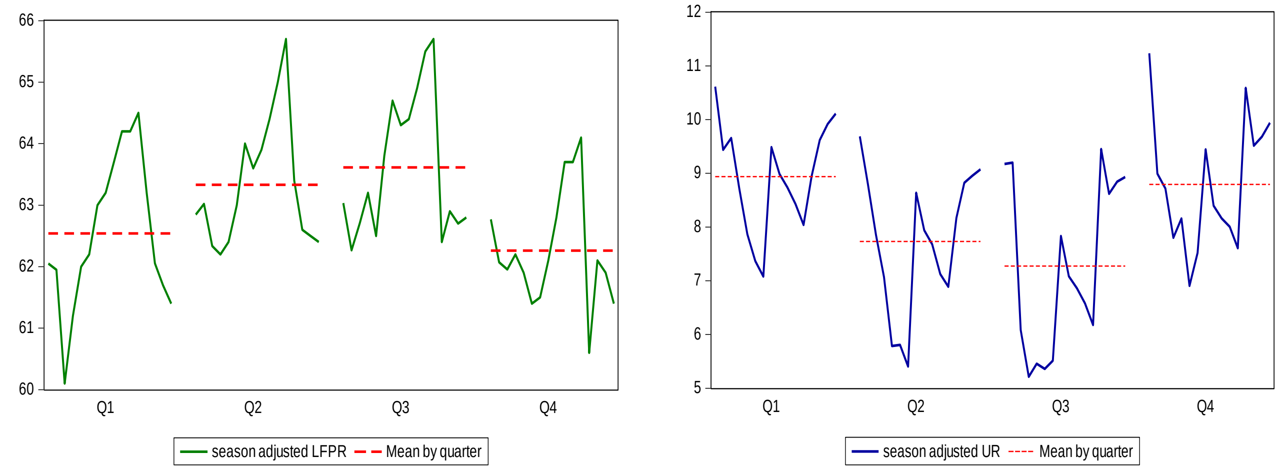
At the same time, conducting a comparative statistical analysis of seasonal series properties of *LFPR* and *UR*, we find out that the unemployment rate shows seasonal fluctuations, opposite to those revealed by economic activity coefficient. In particular, in the second and third quarter, the unemployment rate is relatively high, and on the contrary the economic activity of the population is low (Figure 3), which may be caused by anticipation of bad prospects for employment and the discouraged effect of individual employees in the short term.

Deepening the analysis and examining the correlation among seasonally adjusted series, that is series, from which seasonal factors were eliminated using the moving average methods, and we get opposite conclusions and positive correlation coefficient (Figure 4).

Therefore, it can be confirmed that a seasonal rise in unemployment causes a short-term reduction in the coefficient of labour force participation, while in the long term Ukrainian households show increased economic activity and growth in the rate of entry into the labour force in response to an increase in the unemployment rate and the corresponding reduction of their income.

Figure 3

The seasonal behavior of the labor force participation rate and unemployment rate

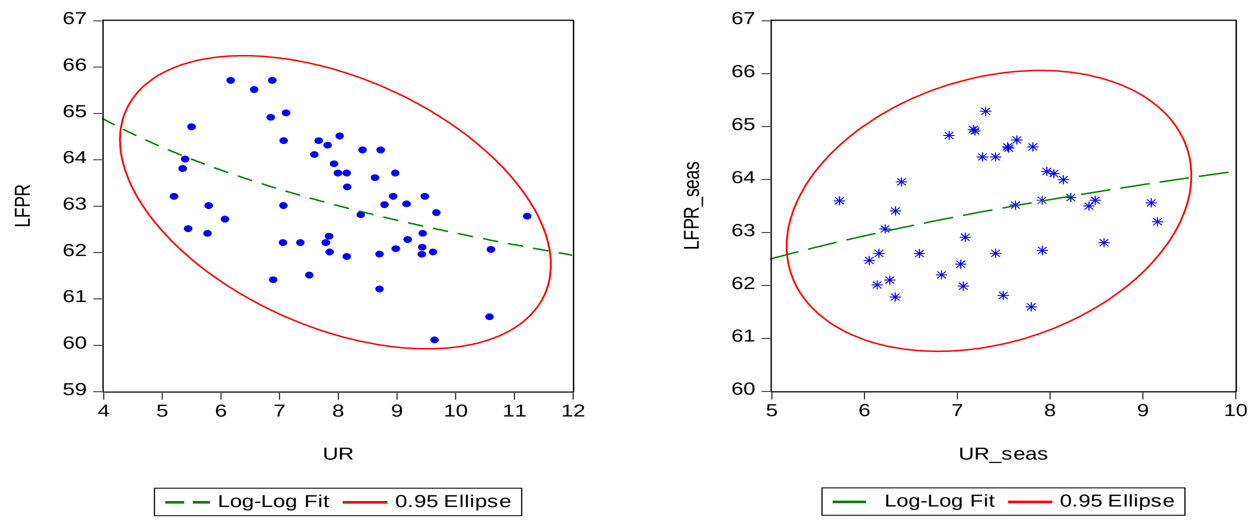


(a) (b)

Source: data of the State Statistics Service of Ukraine, elaborations of the authors.

Figure 4

The correlation between LFPR and UR



(a) (b)

Source: data of the State Statistics Service of Ukraine, evaluations of the authors.

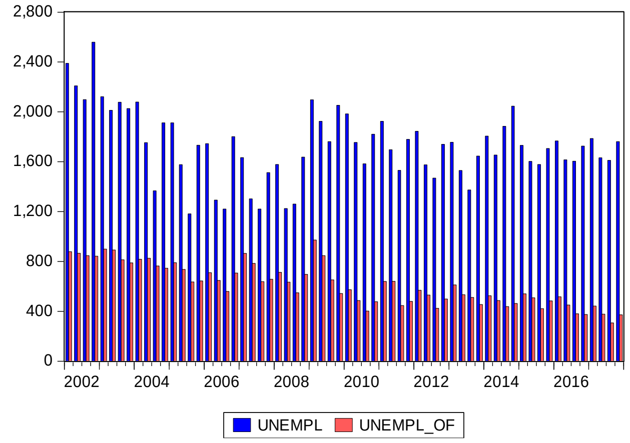
In Ukraine besides the unemployment rate which is determined by the International Labour Organization also the registered unemployment rate (*UROF*) is calculated. According to current legislation registered unemployed are people of working age who are registered in the local public employment services in Ukraine and receive unemployment benefits. Since social assistance to the unemployed in Ukraine is low and moreover the procedure to obtain it for many unemployed is difficult, many people do not register as unemployed at the labor market so the registered unemployment rate (RUOF) is significantly lower than the unemployment rate defined by ILO (*UR*) (Table 1). Analysis of the ratio of *UROF* and *UR* enables to estimate the effectiveness of public policy on preventing mass unemployment and to some extent the degree of people confidence in the state on the issue of employment, compulsory state social insurance against unemployment especially at the regional level.

Studying the registered unemployment rate in Ukraine *UROF* and relationship between it and the economic activity of population, we observe a negative correlation coefficient (Table 2), but we should note that this relationship weakens after 2009. The exposed trends are also accompanied by a weakening of the connection between *UR* and *UROF*. Generally, statistical analysis shows that since 2009 Ukraine has been experiencing a sharp decrease in the percentage of unemployed who are applying for unemployment benefits (Figure 5a). The calculations show that during years 2005—2008 about half of the actual unemployed became registered at employment centers, which is about 700 thousand people from 1.5 million unemployed, but starting from 2009 this number is only 30% (560 thousand. from 1.7 million). As a result, despite the fact that unemployment rate UR since 2009 has increased by an average of 1.3% (Figure 2, Table 1), the registered unemployment rate UROF on the contrary decreased by an average of 0.8% (Figure 5b, Table 1).

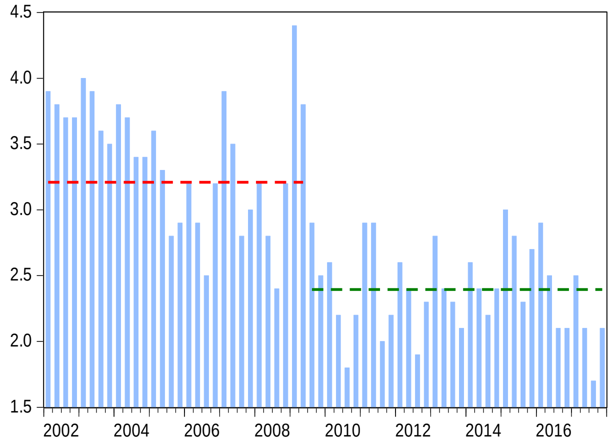
Therefore, empirical analysis shows that the increase in population economic activity in Ukraine is caused by joining new employees who are actively searching for a job however, despite the fact that they are unemployed, they are not officially registered in employment centers.

Figure 5

Dynamics of (a) the number of unemployed and the number of officially registered unemployed; (b) the dynamics of registered unemployment rate



(a)



(b)

Source: data of the State Statistics Service of Ukraine, evaluations of the authors.

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 Ukraine the largest 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 (Baranik, 2009), disparity between education system or professional training of specialists and needs of modern production, besides that an uneven demand for age criterion, the outflow of highly skilled personnel abroad and illegal emigration. V. Kokhan (2013) draws attention to the problems of observance and protection of labor rights of employees involved in non-standard employment, I. Khlevnaya (2013) shows existing problems of employment in rural areas. A. Yanishevska (2014) 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 (2013) 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.

Evaluation of assymetric affects in reaction on shocks of different signs

The number of scientists devote their articles to investigation of economic processes asymmetry. are devoted to the works of Ukrainian scientists. Researchers substantiate the presence of socio-demographic, informational, structural, market, territorial and gender asymmetries in the labor market, various issues of spatial asymmetry in the labor resources allocation of regions (O. Krasnonosova, 2013), determine the indicators and factors of its formation. In particular, V. Miha (2012) performed the analysis of trends in the development of the rural labor marke based on asymmetric assessment; A. Kolot (2011) revealed some forms of asymmetry in the field of social and labor relations and indicated the factors that destabilize the social and labor sphere. A. Ganchuk (2012) suggested a quantitative method for estimating the length of a recession based on the usage of the asymmetry index of time series. Ukrainian scholars point out that to resolve existing socio-economic problems, it is necessary to strengthen the social responsibility of all the institutions of society. Among others, A. Maslov (2012) proposed to solve the problem of information asymmetry; O.Shubna (2011) developed the index of regional asymmetry and proposed the concept of regional socio-economic programs. However, the question of the asymmetry in the reaction of the labor market to macroeconomic shocks and disturbance, depending on their size and direction, remains unsolved for Ukraine.

Analysis and study of asymmetry in responses to the shocks of various economic indicators by foreign scientists are based on the study of asymmetric nonlinear models of time series. In the early work of W. Wecker (1981), the properties of asymmetric moving average processes were described for the first time and the asymmetry of several indices of industrial producer prices in the USA was estimated. S. Elwood (1998) revealed the asymmetry of the impact of innovations to the gross national product, as well as to the volume of industrial products on the basis of threshold auto-regression models. G. Koutmos (1999), R. Kumar and R. Dhankar (2010) obtained the empirical evidence that the conditional volatility of income is asymmetric in the sense that negative disturbance (bad news) significantly affects volatility rather than positive. A. Diongue and D. Guégan (2007) proposed the study of asymmetric seasonal properties of time series behavior based on the seasonal hyperbolic APARCH model. L. Kilian and R. Vigfusson (2011) used vector autoregressive models to evaluate asymmetric feedback functions and showed that the dynamics of oscillations of output, which occur as a result of deviations from equilibrium, had different amplitudes in different directions.

Considering the considerable interest in studies of asymmetry in the social and labor sphere of the national economy and the experience of foreign studies, in today's conditions of economic instability in Ukraine, further development of econometric modeling is necessary, which would reveal and characterize the asymmetric behavior of indicators of the domestic labor market.

Given the symmetry assumption of responses to shocks with different signs, scientists use well-known linear model for one-dimensional modeling of the behavior of economic indicators. In particular, the popular tools are an autoregressive AR(*p*) model

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + ... + \alpha_p y_{t-p} + u_t, \tag{1}$$

moving average model, MA(*q*),

$$y_t = \beta_0 + u_t + \beta_1 u_{t-1} + ... + \beta_p u_{t-q}, \tag{2}$$

mixed moving average autoregressive ARMA(*p*,*q*) model

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + ... + \alpha_p y_{t-p} + u_t + \beta_1 u_{t-1} + ... + \beta_p u_{t-q}, \tag{3}$$

as well as nonlinear time series models

$$y_t = \alpha_0 + \sum_{i=1}^{\infty}\alpha_i y_{t-i} + \sum_{j=1}^{\infty}\sum_{k=1}^{\infty}\alpha_{jk} y_{t-j} y_{t-k} + \sum_{l=1}^{\infty}\sum_{m=1}^{\infty}\sum_{s=1}^{\infty}\alpha_{lms} y_{t-l} y_{t-m} y_{t-s} + ... + u_t \ , \qquad (4)$$

and bilinear models

$$y_t = \alpha_0 + \sum_{i=1}^{\infty}\alpha_i y_{t-i} + \sum_{j=1}^{\infty}\beta_j u_{t-j} + \sum_{k=1}^{\infty}\gamma_k y_{t-k} u_{t-k} + u_t \ . \qquad (5)$$

In each of these models, y_t denotes a time series whose observation is known, u_t is a sequence of independent equally distributed random variables that are not directly observed, α_i, β_j and γ_k are unknown parameters of the models. If the sequence of innovations u_t is determined by a sequence of random variables with an asymmetric density function, in particular, in the case of a logarithmically normal distribution, then the previous models describe the behavior of economic time series with asymmetric marginal or conditional probabilities density.

However, in the behavior of many economic variables, researchers identify asymmetry of another type. Namely, short-term fluctuations in economic indicators show a different asymmetric reaction to positive and negative disturbances, which can not be described by models (1) - (5) with an asymmetric distribution of innovations. As a result, the dynamics of such asymmetric time series in different periods is characterized by different properties, which depend on whether the values of innovation are positive or negative.

Tthere are many types of shocks that have an impact on the processes of the labor market. In particular those are labor supply shocks, labor demand shocks, technological shocks, wage shocks as well as shocks of aggregate demand and supply that include demographic shocks, migration shocks, shocks that cause structural changes in economy, real demand shocks, changes in taxes, welfare, factors of monetary policy and shocks at the currency markets, inflation expectations and so on. Some of these shocks have a long-term impact while others have a short-term impact and moreover the value of these effects is different for different shocks (Oliskevych, 2015). During the modeling we are going to consider specific average dynamic effect from various shocks and divide shocks into positive (those that cause positive deviation of an indicator) and negative (shocks with a negative sign).

Typically for modeling of aggregate output and labor market indicators, the choice of theoretical basis for modeling is based on different theories regarding their stochastic nature and the assumption of symmetry. However, theoretical models of the real business cycle argue that technological shocks primarily affect the dispersion of output, and its level is described by the model of random walk (Ljungqvist, 2004). At the same time, many researchers believe that an important source of changes in the GDP dispersion are positive technological shocks, but do not support an idea of the existence of negative technological shocks, insisting that technological regression is rare. On the other hand, Neo-Keynesian theories focus on demand shocks as sources of significant changes in dispersion of output and use price rigidity to explain short-term deviations from the natural level of production, assuming that the effect of the shocks of both signs is symmetric. So, if the observed fluctuations in output and employment are the result of demand shocks and significant technological innovations, then in average, the positive shocks have a longer impact than negative shocks. As a result, the magnitude of influence for positive and negative disturbances on economic activity, unemployment, employment and productivity can be asymmetrical.

We conducte the evaluation of the impact of shocks with different signs and measure their correlation with future values of the labor market indicators by means of nonlinear threshold specifications which interpret disturbance as unobservable components of a times series. Taking into account the differences between the effects of the influence of positive and negative innovations, we include into the model a threshold variable. Thus, we consider models that take into account several behavior modes depending on the specific value of the indicator variable, which characterizes the past value of disturbances. If disturbance is positive the adjustment occurs in accordance with the first mode whereas the alternative dynamics of series is determined by the second mode for the negative disturbance.

Assymetric Moving Average Processes

Asymmetric threshold-disturbance moving average model of the first order has the form (Wecker, 1987)

$$y_t = u_t + \beta^+ u^+_{t-1} + \beta^- u^-_{t-1} , \tag{6}$$

where u_t defines a sequence of independent identically distributed random variable, $u^+_t = max \{u_t, 0\}$ – sequence of positive innovation, $u^-_t = min \{u_t, 0\}$ – sequence of negative innovation, β^+ i β^- –unknown model parameters. When the two filters of the asymmetric model are identical ($\beta^+ = \beta^-$), than an asymmetric model TDMA (1) is reduced to a symmetric MA model.

$$y_t = u_t + \beta u_{t-1}. \tag{7}$$

Unlike the symmetric MA(1) model (7) with zero mean, the expectation of asymmetric MA(1) model (6) is a function of its parameters and, in the general case, is nonzero. Therefore, the expectation is determined by the formula

$$\mu = \beta^+ \int_0^{\infty} u^+ \varphi(u^+) du^+ + \beta^- \int_{-\infty}^{0} u^- \varphi(u^-) du^- = (\beta^+ - \beta^-) / \sqrt{2\pi} , \tag{8}$$

The variance of time series is

$$\gamma_0 = 1 + ((\beta^+)^2 + (\beta^-)^2) / 2 - \mu^2 , \tag{9}$$

the first order covariance is

$$\gamma_1 = (\beta^+ + \beta^-)/2\,, \tag{10}$$

and high order covariances equal zero. Since the symmetric model (7) is a partial case of an asymmetric model (6), the expectation and autocorrelation of a symmetric model can be determined if the parameters (8), (9) and (10), β^+ and β^-, are equal to each other. Hence, we get well-known results for MA (1) model: $\mu = 0$, $\gamma_0 = 1 + \beta^2$, $\gamma_1 = \beta$

A special case is model with parameters of the asymmetric model that are equal in absolute value but opposite in sign $\beta^+ = -\beta^-$. In this case, an asymmetric series whose dynamics is described by the TDMA (1) model, can not be distinguished from the simple iid sequence on the basis of an autocorrelation function. For this model

$$\mu = 2\beta^+ / \sqrt{2\pi}\,, \quad \gamma_0 = 1 + ((\pi - 2)/\pi)(\beta^+)^2\,, \quad \gamma_1 = 0\ . \tag{11}$$

As a result, the predicted values of this sequence are characterized by a forecast error variance $1 + ((\pi - 2)/\pi)(\beta^+)^2$ that exceeds the forecast error variance which would have been made using a true asymmetric model.

Note that since both the asymmetric TDMA(1) and the symmetric MA(1) models are characterized by zero auto-correlation coefficients for orders that are greater than one, the common analysis by autocorrelation function don't make possible to determine whether the model is asymmetric, or symmetric. In addition, symmetric and asymmetric MA(q) models, similar to MA(1) models, are characterized by autocorrelation functions that acquires zero values for lags greater than *q*. If $\beta_i^+ = -\beta_i^-$ (*i = 1, 2, ..., q*) then the asymmetric TDMA(q) model has zero autocorrelations for all lags, and then, based on the study of the sample autocorrelation function, such a series can not be distinguished from the simple sequence of independent random variables.

We conduct an empirical analysis of processes asymmetry on the Ukrainian labour market and difference in the persistence of positive and negative shocks. Esspecially, we investigate the main labor market indicators suah as: *RGDP* – real groos domestic product (mln hrn); *EMPL* – employment (thousand person); *PROD* –

labor productivity (thousand hrn. per person); *LFPR* – labor force participation rate (%); *UR* – unemployment rate defined by International Labor Organization methodology (%); *UROF* – registered unemployment rate (%).

We verify the symmetry of reaction to positive and negative shocks of labor market indicators based on the evaluation and analysis of TDMA and TDAR models. Research is conducted for level of the variables and their natural logarithms, the first difference of the series and their natural logarithms and for seasonal difference. Worth noting that a time trend was previously eliminated from all series and they were seasonally adjusted (depending on detected statistical properties of a series or using regression specifications with dummy variables, which determine the seasonal factors or by seasonally adjusted moving average multiplicative methods). Testing of stationarity was made on the basis of ADF unit root test, PP and KPSS tests.

Table 4 shows some results of the modeling. In particular, parameters estimation of asymmetric models and corresponding symmetric models, for which both coefficients are identical, as well as meaning of the likelihood ratio test statistic. Estimation was performed using conditional maximum likelihood (ML).

In order to test asymmetry, we use the statistics of the likelihood ratio (Ljungqvist, 2004)

$$LR = -2(\ln L_R - \ln L_{UR}) = 2\ln[(\sigma\wedge_s / \sigma\wedge_{as})^n], \qquad (12)$$

where $\ln L_R$ is the logarithm of the likelihood function and $\sigma\wedge_s$ is the estimation of the residuals standard deviation found under the condition of the symmetric hypothesis, $\ln L_{UR}$ is the logarithm of the likelihood function and $\sigma\wedge_{as}$ is the estimation of the residuals standard deviation for the alternative (asymmetric) hypothesis. This statistics has an asymptotic chi-square distribution whose degree of freedom is equal to the number of restrictions. The evaluated values of the likelihood ratio statistics are given in the last column of the Table 4.

Table 4

The results of symmetric and asymmetric moving average models

Series	Symmetric model		Asymmetric model			LR-statistics
	β	$(\hat{\sigma}_s)^2$	β^+	β^-	$(\hat{\sigma}_{as})^2$	
Labor Force Participation Rate						
Δ_4 ln LFPR	0,26	0,0044	0,25	0,27	0,0044	0,0023
Δ ln LFPR	-0,67	0,0049	-0,65	-0,82	0,0046	2,8430*
Unemployment Rate						
UR	0,77	29,6603	0,99	0,61	27,3423	**3,8994****
Δ_4 UR	0,88	39,9504	0,99	0,24	37,5826	2,7493*
Registered Unemployment Rate						
UROF	0,87	2,7179	0,99	0,77	2,6724	0,8287
Δ_4 UROF	0,99	5,9336	0,99	0,99	5,9336	0,0000
Labor Productivity						
Δ ln PROD	-0,05	0,2035	-0,06	0,04	0,2032	0,0718
Δ_4 ln PROD	0,81	0,1042	0,94	0,66	0,1032	0,4332
Employment						
ln EMPL	0,29	0,0097	0,51	0,07	0,0093	2,0585
Δ_4 ln EMPL	0,27	0,0141	-0,05	0,55	0,0128	**4,4352****
Real GDP						
ln RGDP	-0,30	0,1376	-0,01	-0,99	0,0808	**5,8556****
Δ ln RGDP	-0,01	0,2008	-0,05	0,31	0,1980	0,6910

Note: * statistically significant at 10% level, ** – at 5% level.

Source: estimation of authors.

Analyzing the results of the simulation, we find that for the various adjusted by trend and seasonality transformations of the indicators, especially registered unemployment rate, labor productivity and the percentage of economic activity, the sum of the residuals squares for symmetric and asymmetric MA models does not differ statistically significantly. The value of LR-statistics does not allow a rejection of the hypothesis of symmetry, and therefore it can be argued that these series generally symmetrically react to positive and negative shocks of the previous period.

For *UR*, *EMPL* and *RGD*P series, the hypothesis about the symmetry of the MA process is rejected at 5%. At the same time, the parameters of the asymmetric moving average process differ, indicating that positive and negative innovations have different effects on the behavior of the unemployment rate, the number of employed and real GDP, and therefore their forecasts, based on previous innovations, must take into account differently a sign of previous disturbance. In particular, positive shocks do not statistically significantly change the growth rates of nominal employment whereas the negative shoks reduce them significantly (sensitivity to negative changes is 50%).

For *RGDP* series, we find that the parameter β^{+} don’t significantly differ from zero and the parameter β^{-} don’t differ from -1 that suggests that positive disturbances constantly change the level of real GDP (according to the random walk process), whereas the negative shocks lead to significant but temporary deviation from the trajectory of its natural level.

Asymmetric Autoregressive Processes

To identify the asymmetry in the duration of the effects of various shocks, consider also the modeling of labor market indicators based on asymmetric auto-regression time series models. As in the case of MA processes, we investigate the differences in the effect magnitude for two types of shocks: positive and negative.

The stationary autoregressive AR(1) process

$$y_t = \varphi y_{t-1} + \varepsilon_t , \tag{13}$$

where φ is autoregressive parameter and $\varepsilon_t \sim NID[0,\sigma_\varepsilon^2]$, can be represented by MA(∞) form

$$y_t = \sum_{i=0}^{\infty} \varphi^j \varepsilon_{t-j} , \tag{14}$$

that define the impact of all previous disturbances. In the case of asymmetry, the observed series can be expanded into two components (Elwood, 1998), one of which measures aggregate changes associated with the effect of positive shocks, and the other describes the changes associated with the influence of negative perturbations.

Asymmetrical first order threshold-disturbance autoregressive model can be represented as a nonlinear model, which includes system (Elwood, 1998)

$$y_t = m + yp_t + yn_t , \tag{15}$$

where m – constant, yp_t – unobserved component that receives all non-negative shocks to the observed variable and yn_t – unobserved component that receives all the negative shocks

$$y_t^p = \sum_{i=0}^{\infty} (\varphi_p)^j \varepsilon_{t-j} , \qquad y_t^n = \sum_{i=0}^{\infty} (\varphi_n)^j \varepsilon_{t-j} . \tag{16}$$

Equation (16) can be represented as a non-linear model that encompasses the system

$$y^{p}_{t} = \varphi_p\, y^{p}_{t-1} + u_t \quad \text{and} \quad y^{n}_{t} = \varphi_n\, y^{n}_{t-1} \quad \text{for all } u_t > 0\,; \tag{17}$$

$$y^{n}_{t} = \varphi_n\, y^{n}_{t-1} + u_t \quad \text{and} \quad y^{p}_{t} = \varphi_p\, y^{p}_{t-1} \quad \text{for all } u_t < 0\,. \tag{18}$$

If $\varphi_p = \varphi_n$, then TDAR(1) model (15)—(18) is equivalent to the standard AR(1) model. If $\varphi_p \neq \varphi_n$, then an effect of positive shocks influence differs from the effects of negative shocks influence and threshold specification characterizes asymmetry.

Table 5

The Estimation Results of Symmetric and Asymmetric Autoregressive Models

	Labor Force Participation Rate		Registered Unemployment		Unemployment Rate (ILO)		Labor Productivity		Employment	
Parameter	*Δ ln LFPR*		*UROF*		*UR*		*ln PROD*		*Δ ln EMPL*	
	AR	TDAR	AR	TDAR	AR	TDAR	AR	TDAR	AR	TDAR
φ	-0,29	–	0,01	–	0,01	–	0,07	–	-0,12	–
φ_p	–	-0,14	–	0,09	–	0,08	–	0,02	–	0,02
φ_n	–	-0,42	–	-0,04	–	-0,07	–	0,01	–	-0,26
$(\hat{\sigma})^2$	0,0065	0,0060	5,2654	3,8151	54,664	34,997	0,2367	0,1513	0,0105	0,0100
χ^2	3,8769**		15,7865***		21,8507***		21,9083***		2,7353*	
Parameter	*Δ_4 ln LFPR*		*Δ_4 UROF*		*Δ_4 UR*		*Δ_4 ln PROD*		*Δ_4 ln EMPL*	
	AR	TDAR	AR	TDAR	AR	TDAR	AR	TDAR	AR	TDAR
φ	0,36	–	0,73	–	0,57	–	0,84	–	0,36	–
φ_p	–	0,34	–	0,46	–	0,71	–	0,81	–	0,02
φ_n	–	0,46	–	0,88	–	0,37	–	0,45	–	-0,63
$(\hat{\sigma})^2$	0,0042	0,0042	7,1948	6,4005	36,232	34,018	0,0680	0,0679	0,0135	0,0122
χ^2	0,2151		5,2644**		2,8369*		0,0965		4,4337**	

Source: estimation of authors.

Table 5 shows the results of parameters estimation for asymmetric TDAR models corresponding to their symmetric models, as well as the value of the likelihood ratio statistics for the time series that characterize the indices of the Ukrainina labor market. Testing of asymmetry on the basis of autoregressive models shows a significant asymmetry in the persistence of shocks of all labor market indicators.

The modeling shows that the coefficient of participation in the work force reveals asymmetry in the first differences of the logarithms. The growth rates of the percentage of economic active population respond differently to positive and negative shocks. In particular, positive disturbances lead to a slight decrease whereas the negative disturbance increases them. In this case, according to the results of modeling, negative disturbances have a threefold longer and more persisted impact on the change in the percentage of economic activity than positive. In times of crisis, households, in order to prevent income losses, increase their labor supply. Particularly, young people and older people show increased activity in job searching which leads to an increase in the coefficient of participation in the workforce. Therefore, it can be argued that long periods of economic instability and recession during 2002-2013 and a significant asymmetric reaction to the increase in the percentage of economic activity in response to negative shocks are the reasons for the growth of the labor force participation rate observed during this period. This partly compensates the negative impact of the fall in total number of working-age population on the labor market development.

Both indicators of unemployment are asymmetric in the levels as well as their annual growth rates are asymmetrical. Shocks that have a positive impact on the economy (and accordingly negative to unemployment) cause a decrease in UROF and UR, and shocks that have a negative impact on the economy (and thus positive to the level of unemployment) increase their levels. However, the magnitude of responses to the shocks of different signs is different.

Table 6 represents the summary of asymmetric evaluation. Testing of asymmetry based on LR likelihood ratio test statistic (Wecker, 1987) demonstrates a significant asymmetry in the persistence of shocks to all investigated labour market indicators.

Modelling shows that both indices of the unemployment rate are asymmetric in levels and have asymmetric annual growth rates.

Table 6

Results of Symmetric and Asymmetric Models Comparison, Testing of Asymmetry

Series	Symmetric MA Model		Asymmetric TDMA Model			LR-Statistic
	β	$(\sigma_S)^2$	β^+	β^-	$(\sigma_{as})^2$	
Δ log *LFPR*	-0.67	0.0049	-0.65	-0.82	0.0046	2.8431*
UR	0.77	29.6603	0.99	0.61	27.3423	3.8994**
UROF	0.87	2.7179	0.99	0.77	2.6724	0.8287
Δ_4 log *PROD*	0.81	0.1042	0.94	0.66	0.1032	0.4332
Δ_4 log *EMPL*	0.27	0.0141	-0.05	0.55	0.0128	4.4352**
log *RGDP*	-0.30	0.1376	-0.01	-0.99	0.0808	5.8556**
Series	**Symmetric AR model**		**Asymmetric TDAR model**			**LR-Statistic**
	φ	$(\hat{\sigma}_s)^2$	φp	φn	$(\hat{\sigma}_{as})^2$	
Δ log *LFPR*	-0.29	0.0065	-0.14	-0.42	0.0060	3.876**
UR	0.01	54.6645	0.08	-0.07	34.997	21.850***
UROF	0.01	5.2654	0.09	-0.04	3.8151	15.786***
log *PROD*	0.07	0.2367	0.02	0.01	0.1513	21.908***
Δ log *EMPL*	-0.12	0.0105	0.02	-0.26	0.0100	2.735*

Note: ***, ** and * indicate significance of the coefficients at 1%, 5% and 10% levels.

Source: evaluations of authors.

In particular, negative economic disturbances have a longer effect on cyclical unemployment (deviation of unemployment rate from its natural level, trajectory of which we have defined considering trending and seasonal series properties) than positive. At the same as modelling shows, influence of negative shocks on unemployment, defined by the ILO, and registered level is the same, while positive shocks affect the unemployment rate more than its registered level.

Labour productivity increases during periods of economic growth as well as during phases of recession. However, we should note that the estimate of autoregressive parameter φ_p is twice as big as the corresponding estimate of φ_n, and therefore, it can be stated that labour productivity stronger and longer responds to positive technological shocks. The modelling also shows that positive deviation from the natural trajectory causes further increase in labour productivity and thus creates trend, while negative deviations are compensated in the next period. At the same time according to the results of TDMA model rates of productivity change ($\Delta_4 \log PROD$) do not show an asymmetric reaction.

Coefficient of participation in the labour force reveals asymmetry in the first difference of series logarithm. The growth rate of economically active population percentage responds differently to positive and negative shocks. In particular, the positive disturbances causing their slight decrease, while negative disturbances increasing them. However, according to the evaluation results, negative disturbances have three times larger and longer impact on the change in economic activity percentage than positive. During crisis periods households in order to prevent loss of income increase their labour supply, that is why young people and the elders show increased activity in job searching, that cause a growth of labour force participation rate.

Registered unemployment rate is characterized by asymmetry of long-term responses to shocks of various signs obtained from autoregressive model structure, while instantaneous effects *UROF* are symmetrical. Meanwhile asymmetric reactions of unemployment rate *UR* is obtained from both models.

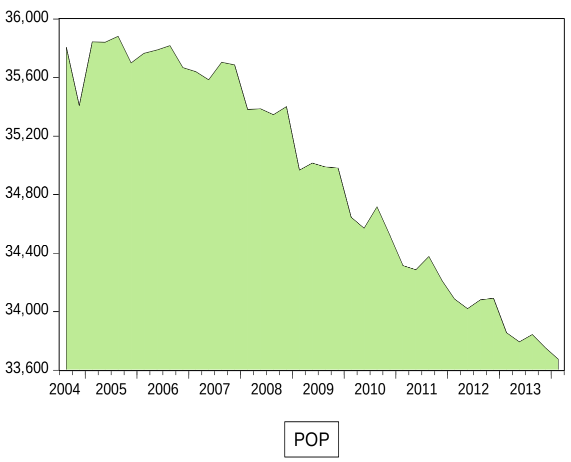
CHAPTER 2

ECONOMETRIC NONLINEAR MODELING OF LABOR MARKET PROCESSES: LOGISTIC SMOOTH TRANSITION MOLELS

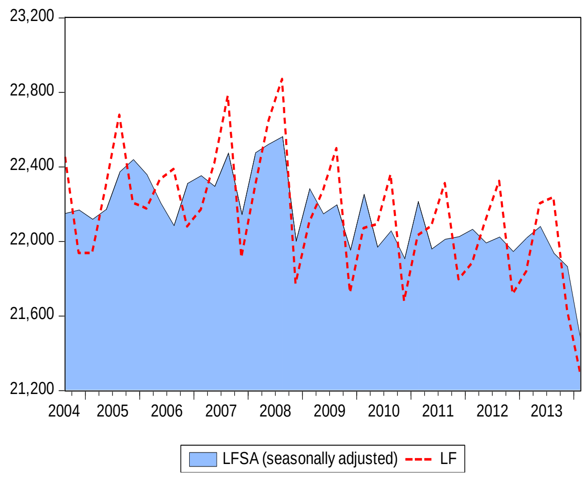
Ukrainian scholars give a considerable attention to research an existing systematic demographic crisis and narrowing the demographic basis for the recreation of human resources. Among others, Y. Tsizhma (2013) put a special focus on the decline in population, reduced life expectancy, fertility decline 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. 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. 6a).

Figure 6

Dynamics in the number of working age population and labor force



(a)



(b)

Source: data of the State Statistics Service of Ukraine, elaborations of the author.

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.

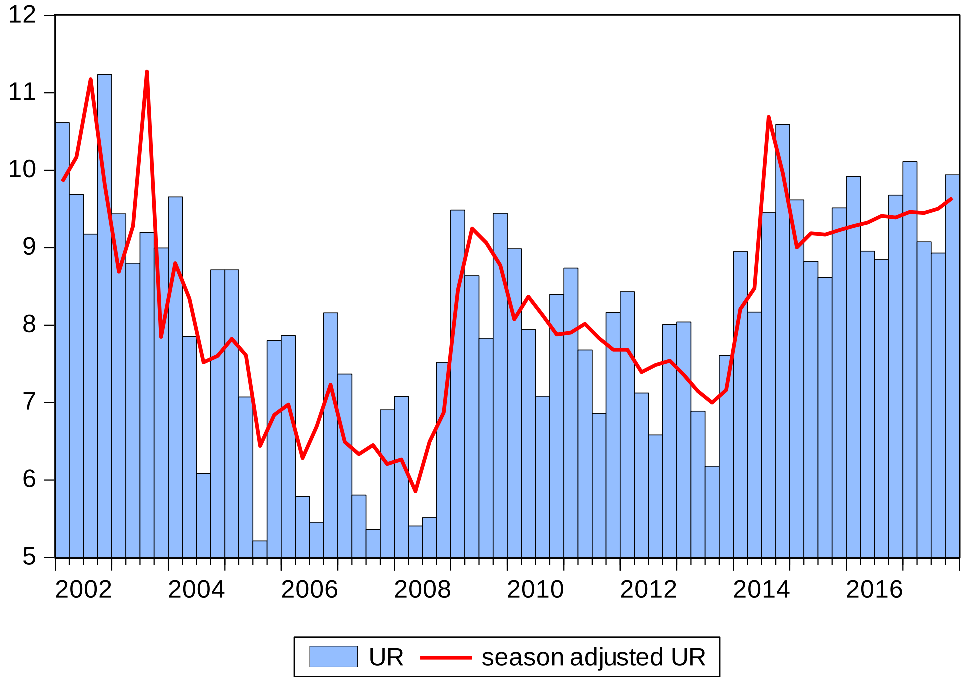
Nevertheless, despite the negative effects which are connected with a reduction in the number of working-age population and rising of unemployment rate, in the same period in Ukraine can be observed increase in economic activity of population and increase of the labor force participate rate (LFPR), as a result the labor force does not show such significant shifts (Fig.6b) 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 (Khlevnaya, 2013), and another driver is an increasing of economic activity of «third age» people(Rad, 2014).

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. 7a and 8a respectively. Fig. 7b and 8b depicts their quarterly growth rates.

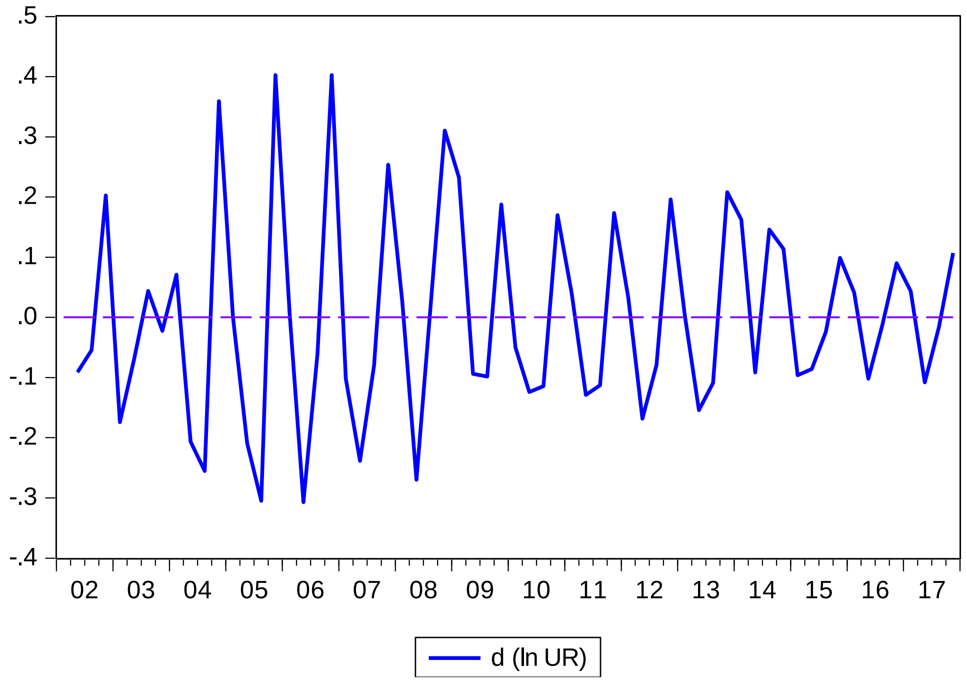
Figure 7

Dynamics of (a) unemployment rate (ILO) (series UR) and

(b) its growth rate over the 2002—2017



(a)

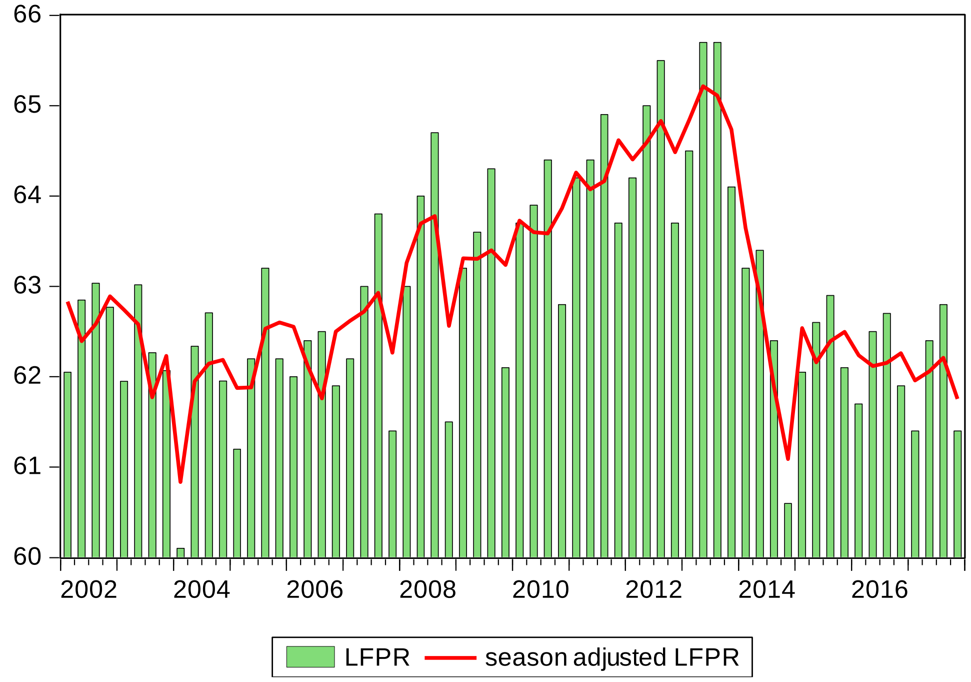


(b)

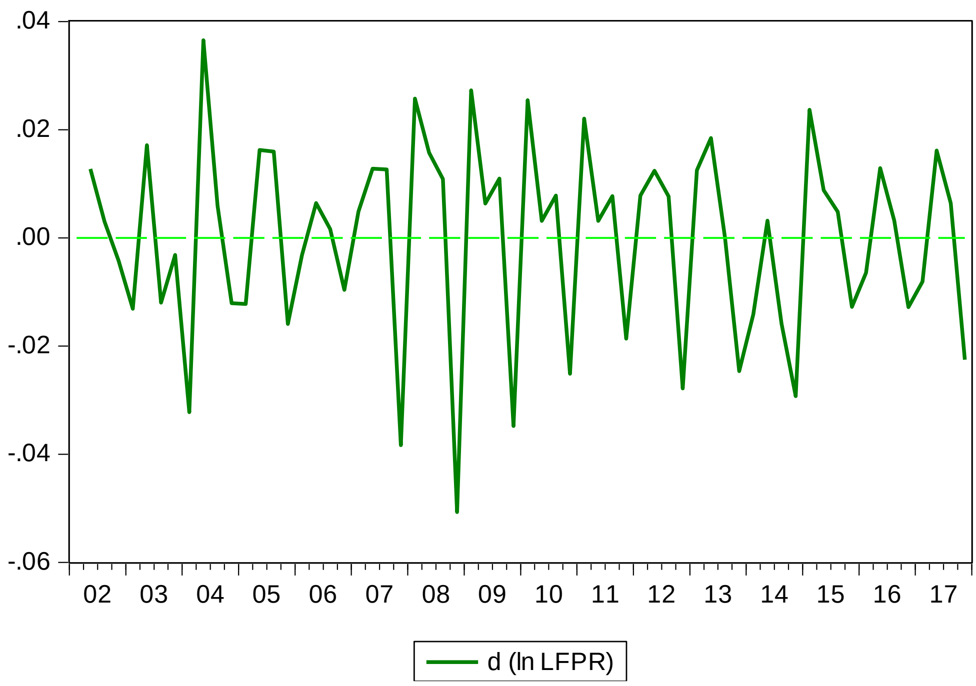
Source: data of the State Statistics Service of Ukraine, elaborations of the author

Figure 8

Dynamics of (a) percent of economic activity of population (series LFPR) and (b) its growth rate over the 2002—2017



(a)



(b)

Source: data of the State Statistics Service of Ukraine, elaborations of the author.

J. Emerson (2011), M. Kakinaka and H. Miyamoto (2012), D. Liu (2014) 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. 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. Gustavsson and Österholm (2012), Salamaliki and Venetis (2014) showed 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 (Hernández and Orraca, 2011). As a 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 (Koop and Potter,1999). 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.

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, Gustavsson (2012) shows that the LFPR in Australia, Canada and the United States are not stationary. Ozdemir, Balcilar and Tanse (2013), 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 (Madsen, Mishra and Smyth, 2008).

Results of the study of *LFPR* series stationarity in Ukraine on the basis of augmented Dickey-Fuller unit root test are presented in Table 7. The test shows that the series is nonstationary, and therefore labor supply response to macroeconomic shocks may vary depending on job prospects.

Table 7

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	-4,180911	0,0834
		0,05	-3,515523	
		0,10	-3,188259	
The null hypothesis: Δ log *LFPR* contains unit root				
intercept	-14,89231	0,01	-3,588509	0,0000
		0,05	-2,929734	
		0,10	-2,603064	

Source: evaluations of the authors.

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 7), 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 [15]. 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 (Lukianenko and Zhuk, .2012). 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. Switching regression models, various Markov switching models and smooth transition regression models are examples of models belonging to this class (Terasvirta, 1994). In the result of conducted econometric analysis and taking into account the experience of foreign studies (Cengiz and Sahin, 2009) 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:

$$y_t = \varphi' z_t + \theta' z_t\, G(s_t; \gamma, \alpha) + u_t = (\varphi + \theta\, G(s_t; \gamma, \alpha))' z_t + u_t\,, \quad t=1,\dots,T \qquad (19)$$

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 γ and vector of location parameters $\alpha = (\alpha_1,..., \alpha_K)'$, $\alpha_1 < ... < \alpha_K$. Representation (19) 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 (19) characterizes the linear component of the system with parameters φ_j ($j=1,...,m$), while the second part $\theta'\, z_t\, G(s_t; \gamma, \alpha)$ describes non-linear component with parameters θ_j. If the model (1) does not contain exogenous variables vector $z_t = (1, y_{t-1}, ..., y_{t-p})$ 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 φ and θ contains $p+1$ coefficients, including intercept and p slope coefficients at lagged values, then the model (19) is one-dimensional smooth transition autoregressive model.

If the transition function that determines the behavior of non-linear part in (19), is given by the logistic function

$$G(s_t; \gamma, \alpha) = 1 / (1 - exp\, (- \gamma \prod_{k=1}^{K} (s_t - \alpha_k))) , \qquad \gamma > 0, \tag{20}$$

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 [19]. For $K = 1$ model parameters $\varphi + \theta\, G(s_t; \gamma, \alpha)$ monotonously change with change of s_t from φ 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 $\gamma \rightarrow \infty$ and is equal to 1/2, if $\alpha_1 = \alpha_2$ and $\gamma < \infty$. Parameter γ defines the slope and α_1, α_2 – allocation of transition function values.

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

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

This function is symmetric around $s_t = \alpha^*$ and has at low and moderate values of the slope parameter γ about the same shape but different minimum value (zero) comparing with the logistic function (20).

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 (19) - (20) 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 (20) by its third-order Taylor expansion around the null hypothesis γ = 0. As a result for testing the following auxiliary regression is estimated

$$y_t = \beta_0'\,z_t + \sum_{j=1}^{3} \beta_j'\,z_t{*}\,s_t^j + u_t\,, \qquad t=1,\ldots,T, \qquad (21)$$

where $\mathbf{z}_t = (1, \mathbf{z}_t^*)'$, $\mathbf{z}_t^*$– m-dimensional vector, $u_t^* = u_t + R_3(s_t,\gamma,\alpha)\ \theta'\mathbf{z}_t$, $R_3(s_t,\gamma,\alpha)$ – remainder of approximation**,** and parameters β_j ($j=1, 2, 3$) can be represented as $\gamma\ b_j$, where b_j are functions from θ and α, $b_j \neq 0$. 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 χ^2 - distribution with three degrees of freedom. However, for small and medium-sized samples χ^2- distribution statistics can be seriously distorted that is why in these cases it is recommended to use the appropriate F - statistic. For the null hypothesis its distribution is approximated with $F[3, T–4m–1]$ Fisher distribution.

Empirical results

Asymmetric behaviour of Ukrainian LFPR indicates the necessity of nonlinear econometric analysis conduction and implementation of comprehensive statistical study of the time series properties. Results of *LFPR* stationarity in Ukraine done on the basis of augmented Dickey–Fuller unit root test, Phillips–Perron unit root test and Kwiatkowski–Phillips–Schmidt–Shin test demonstrate that *LFPR* series is integrated of first order (DF = –2.86, PP = –3.72, KPSS = 0.78 for log *LFPR*; DF = –16.05, PP = –21.16, KPSS = 0.19 for Δlog *LFPR*). It should be noted that because of nonstationarity proportion of economically active population the effectiveness of joblessness measuring by using unemployment rate is controversial because the labor supply response to macroeconomic shocks may vary and depend on job prospects (Madsen, Mishra and Smyth, 2008).

As a result of the conducted econometric analysis, as well as taking into account experience of previous studies (Salamaliki and Venetis, 2014, Cengiz and Sahin, 2014) we selected univariate smooth transition autoregressive model for modelling economic activity of population in Ukraine. STAR models make it possible to model processes for which at some period of time a specific series structure can dominate, which as a result of switching regime will gradually change into other structure (Lutkepohl et al., 2004). The order of lags length, which will be included in a model are chosen on the basis of the Akaike information criterion (AIC), the Hannan-Quinn criterion (HQ) and the Schwarz criterion (SC) comparison for the corresponding linear models. Taking into account seasonality in the series behaviour in the model was included a constant and seasonal variables $S1$, $S2$, $S3$, which take the value 1 respectively in the first, second and third quarters and zero for all other quarters. To account the shift effects taking place as a result of 2008 crisis and after the revolution events in 2014 the model includes certain dummy variables. Evaluation results of autoregressive models with different lags length show that a model which includes three previous delays is the best choice

$$\Delta \log LFPR_t = \boldsymbol{\alpha}' \boldsymbol{Seas}_t + \boldsymbol{\beta}'\boldsymbol{D}_t + \boldsymbol{\varphi}' \boldsymbol{y}_t + \boldsymbol{\theta}' \boldsymbol{y}_t\, G(s_t; \gamma, \boldsymbol{c}) + u_t\ , \quad t = 1,\dots,T, \tag{22}$$

where $\boldsymbol{Seas}_t = (S1_t, S2_t, S3_t)'$ – a vector of seasonal dummy variables; $\boldsymbol{y}_t = (1, \Delta\log LFPR_{t-1}, \Delta\log LFPR_{t-2}, \Delta\log LFPR_{t-3})'$ – a vector of explanatory variables; $\boldsymbol{D}_t = (Shift\_D2008q4_t, Shift\_D2014q1_t, Impulse\_D2008q4_t, Impulse\_D2014q1_t)'$; $\boldsymbol{\alpha} = (\alpha_1, \alpha_2, \alpha_3)'$, $\boldsymbol{\beta} = (\beta_1, \beta_2, \beta_3, \beta_4)'$, $\boldsymbol{\varphi} = (\varphi_0, \varphi_1, \varphi_2, \varphi_3)'$ and $\boldsymbol{\theta} = (\theta_0, \theta_1, \theta_2, \theta_3)'$ – vectors of unknown parameters of the model, $u_t \sim iid\ (0, \sigma^2)$ sequence of innovations. Transition function $G\ (s_t; \gamma, \boldsymbol{c})$ is defined by the general logistic function

$$G(s_t;\gamma,\boldsymbol{c}) = \frac{1}{1+\exp(-\gamma\prod_{j=1}^{N}(s_t - c_j))}, \qquad \gamma > 0, \tag{23}$$

which is a continuous function of the transition variable s_t, slope parameter γ and vector of location parameters $\boldsymbol{c}$. Vector of location parameters $\boldsymbol{c} = (c_1,\dots, c_N)'$ defines threshold values between different time regimes, which are determined by different values of s_t.

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 $\beta_1 = \beta_3 = 0$ [13]. If $\alpha \neq 0$, still the β_2 is closer to the zero vector than β_1 or β_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.

To justify the correctness of using a nonlinear smooth transition model to describe the asymmetric behaviour of a series we use a common methodology for testing the null hypothesis of linearity for the alternative of LSTR-nonlinearity (Lutkepohl et al., 2004).

As potential transition variables we choose the elements of the set $S=\{TREND$, $\Delta\log LFPR_{t-1}$, $\Delta\log LFPR_{t-2}$, $\Delta\log LFPR_{t-3})$ and conduct testing of nonlinearity for each element of *S*. As a result of tests we obtained a p - values for the test statistics that are lower than the acceptable significant level by 5% for the three transition variables from *S* (Table 8), which shows nonlinearity of autoregressive correlations and justifies the need to use LSTR nonlinear models for modelling a coefficient of labour force participation rate.

Table 8

Autoregressive Nonlinearity Test Results

Hypothesis	*TREND*	Δlog *LFPR(-1)*	Δlog *LFPR(-2)*	Δlog *LFPR(-3)*
p-value (*F*)	0.0361**	0.0219**	0.8405	0.0213**
p-value (*F*4)	0.3242	0.0969*	0.4809	0.1371
p-value (*F*3)	0.6065	0.0720*	0.9676	0.1177
p-value (*F*2)	0.0024***	0.1055	0.5437	0.0378**
Adequate model	LSTR1	LSTR2	Linear	LSTR1

Note: *indicates significance of the coefficients at 10%, ** – at 5%, *** – at 1%.

Source: evaluations of the authors.

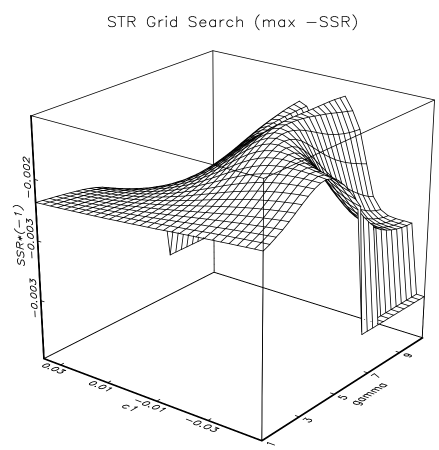
Tests show that adequate may be considered the LSTR1 model with transition variable Δ log $LFPR_{t-1}$ or Δ log $LFPR_{t-2}$ and LSRT2 model with transition variable *Trend*. LSTR1 model allows to model the behavior of asymmetric economic activity in the labor market and allows to describe dependence 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.

Results of the research show that LSTR1 models with transition variables *TREND* or Δ log $LFPR_{t-3}$ and LSRT2 model with transition variable Δlog $LFPR_{t-1}$ may be adequate. Should be noted that LSTR1 and LSTR2 models describing different types of behaviour. The first model (N = 1) has two extreme regimes that differ from each other. In particular, if the transition variable is an indicator of transition between the phases of the business cycle, one regime will correspond to the phase of rising in the business cycle, and the second is associated with the recession phase. LSTR2 model has two similar regimes for both large and small values of transition variable, while the middle regime is different (Lutkepohl et al., 2004).

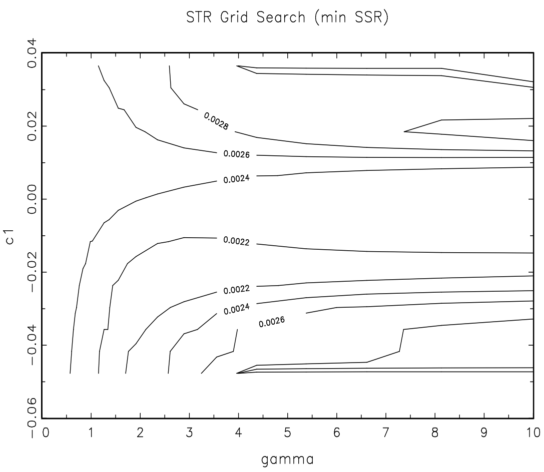
However, estimation of the initial values of the parameters α and γ, and further evaluation and diagnosis of different smooth transition models discover that LSTR1 model with transition variable Δ log $LFPR_{t-1}$ is the best to describe the rate of growth of the economically active population share. Fig. 9 shows the residual sum of squares (SSR) as functions of the two parameters α and γ for this model. In particular, Fig. 9a shows a surface-SSR and therefore determines its maximum, and Fig. 9b – level lines of SSR function, which make it possible to determine the minimum of residual squares sum.

Figure 9

Graphic representation of residual sum of squares as a function of the slope and allocation parameters



(a)



(b)

Source: evaluations of the authors.

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

$$\Delta \log LFPR_t = \varphi_0 + \beta_1 S1_t + \beta_2 S2_t + \beta_3 S3_t + \tag{24}$$
$$+ \varphi_1 \Delta \log LFPR_{t-1} + \varphi_2 \Delta \log LFPR_{t-2} + \varphi_3 \Delta \log LFPR_{t-3} +$$
$$+ G(s_t; \gamma, \alpha)(\theta_1 \Delta \log LFPR_{t-1} + \theta_2 \Delta \log LFPR_{t-2} + \theta_3 \Delta \log LFPR_{t-3}) + u_t,$$

$$G(\Delta \log LFPR_{t-1}; \gamma, \alpha) = 1/(1 + \exp(-\gamma \; (\Delta \log LFPR_{t-1} - \alpha))), \tag{25}$$

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 $\gamma \to \infty$ 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 (25) is monotonically increasing with s_t. Slope parameter γ 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.

Table 9

Estimation results of LSTR1 model for labor force participation rate

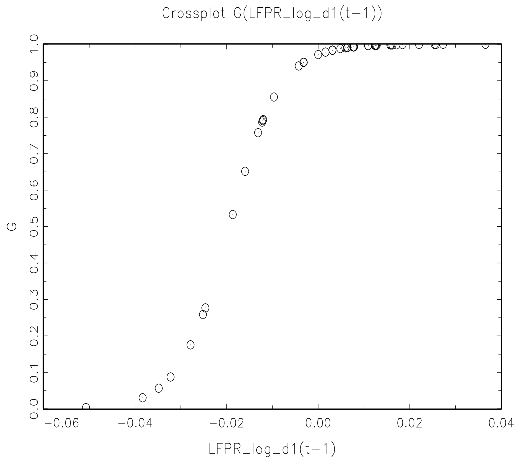
Variable	Linear part of LSTAR model		Non-linear part of LSTAR model	
	Coefficient	*t*-statistics (*p*-value)	Coefficient	*t*-statistics (*p*-value)
Const	-0.0022	-0.1012 (0.9200)	0.01354	-0.5666 (0.5749)
S1	0.0056	0.8753 (0.3880)	—	—
S2	0.0280	4.1089 (0.0003)	—	—
S3	0.0194	3.3998 (0.0018)	—	—
Δ log *LFPR(-1)*	-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)
α	—	—	-0.01938	-2.9427 (0.0060)

Source: estimations of the authors.

The estimated slope parameter γ = 3.49 characterizes the smoothness of this transition and the curvature degree of the transition function (25). Its rather high value shows that the economic activity of population quickly reacts to changes taking place in the labor market (Fig. 10).

Figure 10

Plot of estimated transition function



Source: evaluations of the authors.

Comparison of modeling results based on linear AR(3) model and developed nonlinear model (24)–(25) 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.

Since on the stage of nonlinearity testing we got several possible nonlinear specifications, the choice among them will be done during models estimation and evaluation. Parameters of STR models are estimated by the maximizing the conditional likelihood function and iterative algorithm BFGS. Calculations are done by using econometric package JMulTi. Estimation of initial values ***c*** i γ, and further estimation and evaluation of various smooth transition models indicate that LSTR2 model with transition variable $\Delta \log LFPR_{t-1}$ is also good for describing the growth rate of the proportion of economically active population. The results of parameters estimation for this model which take into account seasonal and dummy variables along with results of estimation for linear autoregressive model are shown in Table 10.

Table 10

Estimation Results of LSTR1 Model for Labor Force Participant Rate

Variable	LSTR model		AR model	
	Coefficient	t-statistics (p-values)	Coefficient	t-statistics (p-values)
Linear Part				
Const	-0.0277	-4.1341 (0.0003)	-0.0236	-3.6281 (0.0008)
Impulse_D2008q4	-0.0163	-2.0399 (0.0513)	-0.0088	-1.2130 (0.2321)
Impulse_D2014q1	-0.0161	-2.0917 (0.0460)	-0.0390	-4.8811 (0.0000)
Shift_D2008q4$_t$	-0.0066	-2.6213 (0.0142)	0.0013	1.2243 (0.2278)
Shift_D2014q1	-0.0079	-0.2139 (0.0355)	-0.0025	-1.3519 (0.1838)
S1	0.0299	4.3337 (0.0002)	0.0326	2.7371 (0.0091)
S2	0.0375	7.3191 (0.0000)	0.0353	5.0602 (0.0000)
S3	0.0277	6.3376 (0.0000)	0.0282	2.3713 (0.0225)
*Δ*log *LFPR(-1)*	4.2333	3.3889 (0.0022)	-0.7242	-5.5316 (0.0000)
*Δ*log *LFPR(-2)*	1.4701	3.9535 (0.0005)	-0.4926	-3.1526 (0.0030)
*Δ*log *LFPR(-3)*	1.3119	3.6457 (0.0011)	-0.5188	-3.8940 (0.0004)

Table 10(continue)

Nonlinear Part				
Const	0.0087	1.0025 (0.3250)	—	—
Δlog *LFPR(-1)*	-5.0271	-4.1215 (0.0003)	—	—
Δlog *LFPR(-2)*	-2.0132	-4.4659 (0.0001)	—	—
Δlog *LFPR(-3)*	-2.0421	-4.2958 (0.0002)	—	—
γ	3.1985	4.1498 (0.0003)	—	—
c_1	-0.0011	-0.0524 (0.9586)	—	—
c_2	-0.0011	-0.0524 (0.9586)	—	—

Diagnostic Statistics		
AIC	-9.8318	-6.2467
SC	-9.1091	-5.8339
HQ	-9.5624	-6.0884
R^2	0.9305	0.7889
Adjusted R^2	0.9288	0.7374
SD of Residual	0.0063	0.0097

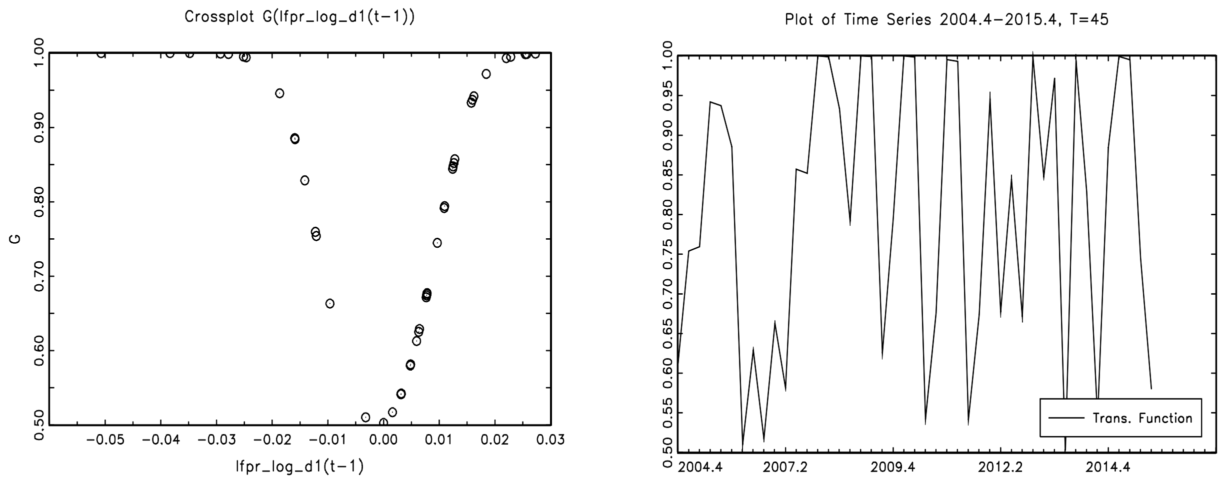
Source: evaluations of the authors.

Comparison of modelling results for linear and nonlinear case reveals a significant reduction of information criteria and standard error of a model as well as coefficients of determination increasing, confirming necessity of nonlinear modelling approaches application. Estimated values of location parameters determine the values at which the changes in the regime of population economic activity are conducted from periods of low growth rates for periods of high values. Modelling shows that the current rate of these changes responds differently to changes in the characteristics of previous states, and indicates that the values amplitude of previous change in labour force participation rate determines the shift in behaviour regime and smooth transition during the time period. Obtained estimated value of slope parameter $\gamma = 3.2$, which characterizes the smoothness of this transition is quite large, indicating that the economic activity of the population quickly react to changes that take place in the labour market.

Figure 11 shows a plot of evaluated transition function $G\ (\gamma, c, s_t)$ as a function of the transition variable $s_t = \Delta \log LFPR_{t-1}$ (Fig. 11a) and dynamics of values for 2004–2015 years (Fig. 11b).

Figure 11

Transition function of model (22) - (23)



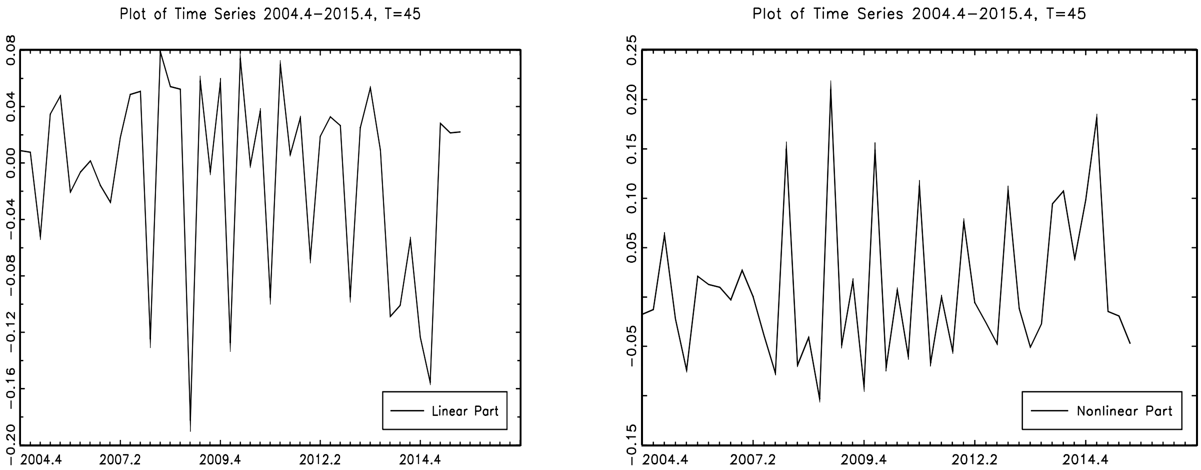
(a) (b)

Source: evaluations of the authors.

Plot of transition function as function of transition variable observation Δlog $LFPR_{t-1}$ shows that the transition is really smooth and relatively asymmetric around the estimated location value. Figure 12 shows the linear $\boldsymbol{\varphi}'\mathbf{y}_t$ and nonlinear $\boldsymbol{\theta}'\mathbf{y}_t\, G(\gamma, c, s_t)$ parts of a series.

Figure 12

Linear and nonlinear parts of a series Δ log *LFPR*$_t$ fitted on the basis of LSTR2 model



(a) (b)

Source: evaluations of the authors.

A comparison of the actual values of a series $LFPR_t$, and values fitted for the two models, namely linear AR model and values $\boldsymbol{\varphi}'\mathbf{y}_t + \boldsymbol{\theta}'\mathbf{y}_t\, G(\gamma,c,s_t)$, defined on the basis of nonlinear LSTAR model that are respectively the sum of linear and nonlinear parts shows that the estimates of LSTAR model give better ex post forecasts than their linear (AR) approach.

Diagnostic of conducted models

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:

$$y_t = \varphi' z_t + \theta' z_t G(s_{1t}; \gamma_1, \alpha_1) + \psi' z_t H(s_{2t}; \gamma_2, \alpha_2) + u_t, \qquad (26)$$

where $H(s_{2t}; \gamma_2, \alpha_2)$ is another transition function which has the following form (24), 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 (26).

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 (25) 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 (24)–(25) also should be checked. For testing the regression (26) is rewritten as

$$y_t = \varphi(t)' z_t + \theta(t)' z_t G(s_t; \gamma, \alpha) + u_t, \qquad \gamma > 0, \qquad (27)$$

where

$$\varphi(t) = \varphi + \lambda_\varphi H_\varphi(t^*; \gamma_\varphi, \alpha_\varphi) \ \text{ i } \ \theta(t) = \theta + \lambda_\theta H_\theta(t^*; \gamma_\theta, \alpha_\theta), \qquad (28)$$

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 (28) for $s_t = t^*$. They characterize two different time varying vectors of parameters whose values vary smoothly between φ and $\varphi + \lambda_\varphi$ and θ and $\theta + \lambda_\theta$

respectively. Equations (27)–(28) 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 χ^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.

Table 11

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_1	1,1917	F[11,19]	0,3549
	H_2	1,2048	F[22,8]	0,4142

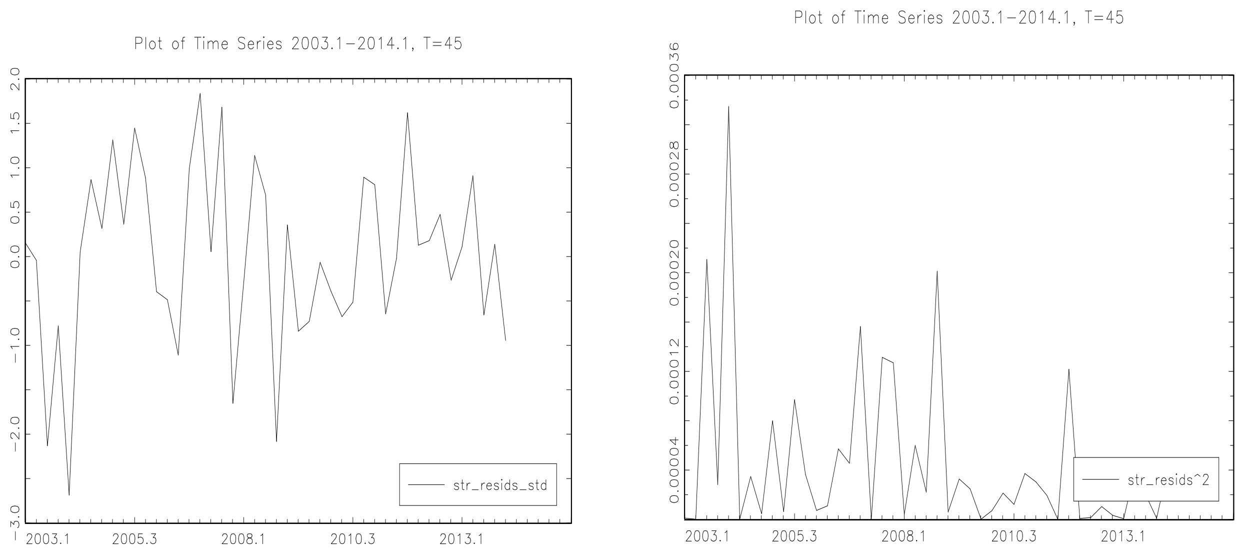
Source: evaluations of the authors.

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 (24)–(25) based on the study of the properties of its residuals, graphic images of which are shown in Fig. 13.

Figure 13

Plot of standardized residuals and residuals squares of LSTR1 model



(a) (b)

Source: evaluations of the authors.

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 (24)–(25) against the alternative of autocorrelation of order not greater than *q* based on the regression of LSTAR evaluated model residuals $(u^\wedge)_t$ of regarding its lagged values $(u^\wedge)_{t-1}$, … , $(u^\wedge)_{t-q}$ 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

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

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 (24)–(25) for different lags orders that are shown in Table 12, confirm their non-autocorellation.

Table 12

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 authors.

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 13 indicate the normal distribution of residuals and absence of conditional heteroskedasticity.

Table 13

The results of testing the normality residuals and ARCH-effects in LSTAR model

ARCH-LM test (8 lags)	χ^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 authors.

Once the LSTR2 model (Table 10) was also estimated, we should check if it adequately characterizes the nonlinearity originally found in the data and test whether there is some non-linearity that was not described by the estimated STR model, and also to examine parameter constancy of the evaluated model. Instability of the model parameters may yield important information about causes of possible misspecification of the model or change of economic relationship that describes the model over time.

Test results of no additive nonlinearity and stability of the model parameters which were based on the use of appropriate LM-type statistics (Lutkepohl et al., 2004) are shown in Table 14. Conducted testings indicate on the stability of the model parameters and absence of nonlinearity, and therefore on the adequacy of choosing LSTR2 model for describing the dynamics of percent of the economically active population in Ukraine.

We carried out a diagnosis of constructed LSTAR model based on the investigation of its residuals properties. The results of testing on autocorrelation in some residual of a model (5) – (6), check of the null hypothesis on absence of ARCH effects in the residues and testing the normality of their distribution based on Lomnicki–Jarque–Bera normality test are shown in Table 7. The results of the tests indicate the residues non-autocorrelation, normality of their distribution and absence of conditional heteroskedasticity.

Table 14

Evaluation Results of LSTR Model

<table>
<tr><td colspan="2" rowspan="2">Test of no additive nonlinearity</td><td colspan="2">Test of no error autocorrelation (LM)</td></tr>
<tr><td>Test Statistic</td><td>p-value</td></tr>
<tr><td colspan="2">p-value (F) = 0.3959</td><td>F (1 lag) = 0.6928</td><td>0.4114</td></tr>
<tr><td colspan="2">p-value (F4) = 0.2941</td><td>F (2 lags) = 0.3367</td><td>0.7168</td></tr>
<tr><td colspan="2">p-value (F3) = 0.2210</td><td>F (3 lags) =0.5324</td><td>0.6638</td></tr>
<tr><td colspan="2">p-value (F2) = 0.7829</td><td>F (4 lags) =0.4803</td><td>0.7499</td></tr>
<tr><td colspan="2">Test of parameter constancy</td><td colspan="2">ARCH-LM test (8 lags)</td></tr>
<tr><td>Test Statistic</td><td>p-value</td><td>Test Statistic</td><td>p-value</td></tr>
<tr><td>F (H1) = 1.9477</td><td>0.1221</td><td>$\chi 2$ = 1.8546</td><td>0.6031</td></tr>
<tr><td>F (H2) = 1.9491</td><td>0.1169</td><td>F = 0.6468</td><td>0.5898</td></tr>
<tr><td colspan="4">Normality Test</td></tr>
<tr><td>LJB=0.2598</td><td>p-value = 0.8782</td><td>Skewness=0.0877</td><td>Kurtosis=3.3283</td></tr>
</table>

Source: evaluation of the authors.

Therefore, the results of statistical tests confirm the adequacy of conducted modeling and correctness of using the nonlinear logistic smooth transition model to describe the behavior of the labor force participation rate in the in Ukraine.

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.

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.

CONCLUSIONS

The effectiveness of socio-economic policy implementation in Ukraine requires a development of qualitative models that allow explaining and predicting trends in unemployment and active participation of population in the labour market. The conducted empiric research shows that the inverse relationship among population economic activity and unemployment rate in Ukraine is short-term. Fluctuations of labour force participation rate are caused by seasonal fluctuations in unemployment rate, while in the long run Ukrainians show increased economic activity and increase in the rate of entering in the labor force. The results of an econometric analysis of labour market indicators show asymmetric responses of shocks with different signs and indicate that negative disturbances increase their volatility much more than positive, which requires consideration asymmetry in their response to various market conditions changes in modelling and predicting future trends of development processes in social and labor sphere. It is found that prolonged periods of economic instability and recession during 2002—2013 years and a significant asymmetric reaction of economic activity percent increase in response to negative macroeconomic shocks are causes of participation in the labor force coefficient growth that is observed during this period and partially compensate the negative impact of the decline in working-age population.

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. Modelling shows that an economic activity of population quickly reacts to changes that take place in the labour market. In times of crisis Ukrainian households increase labour supply and show increased activity in job search in order to prevent the decline of their income. Created model makes it possible to increase the adequacy of modelling and forecasting of future trends on the labour market in Ukraine in order to implement measures designed to maintain and further improve productivity and percent of economic activity.

In order to increase economic activity of population in Ukraine it is necessary to introduce changes in the taxation system of labor remuneration that would reduce informal employment (in Ukraine it is about 23% of all employees), growth of employment in the official sector. Considering the fact that the highest unemployment rate in Ukraine is observed among bachelors it is advisable to encourage the creation of temporary jobs, that is a rarity in Ukraine and which would be available to students with a bachelor degree that continue studying. That would increase the employment rate among young people. Increasing the labor force participation rate can also be achieved through the promotion of employment among the inactive part of population not included in the workforce such as older people, women, the disabled and ethnic minorities. At the same time the stabilization of political situation, attraction of investments and positive technological changes will make it possible to increase labor productivity and reduce the outflow of labor force abroad. Considering the complicated demographic situation and high expected load on younger generation in Ukraine it is also necessary to pay more attention to quality of education and to modernize its direction and all that in the future will lead to the increase of labor productivity in the country.

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.

Timeliness and effectiveness of policy in the long term will allow prevent threats to the national labour market that are associated with the influence of negative demographic trends and an aging population.

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