UDC 330.43/519.862/331.5

THE MODELLING OF REGISTERED UNEMPLOYMENT RATE NONLINEAR DYNAMICS IN UKRAINE BY MEANS OF THRESHOLD AUTOREGRESSION

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Lukianenko I. H., Oliskevych M. O.

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In conditions of unstable economic development of the national economy the analysis of labour market and forecast of employment and unemployment rate dynamics is of primary importance for social responsibility provision and social risks reduction in society. The purpose of the research is the empirical analysis of nonlinear dynamics of registered unemployment rate in Ukraine in conditions of increased risks and asymmetry of information and the development of corresponding complex of nonlinear threshold autoregressive models. Methodology approach is based on methods of economic theory and economic and mathematical tools. Econometric methods of analysis of nonlinear time series with non-traditional functions of distribution have been used. In the result of the empirical investigation the application of threshold autoregressive models has been justified and the row of nonlinear econometric specifications that help to explain asymmetric dynamics of unemployment has been evaluated. The resulting threshold function and value of threshold parameter, estimated on the basis of real information, determine the branching of TAR model into two different modes of behaviour that in different ways characterise dynamics of unemployment growth and fall and allow forecasting the phases of employment fall and growth in the short term. Application of the developed nonlinear econometric models of registered unemployment rate dynamics adds to characteristics of labour sector in Ukraine and allows forecasting more precisely the effects of government measures in the sphere. The defined nonlinear character of dynamics of unemployment rate certifies non-Walrasian features of labour market in Ukraine and reveals its uneven and asymmetric cyclic behaviour.

Key words: *unemployment, employment, autoregressive model, TAR model, threshold parameter, labour market*

Pic.: *2.* ***Tabl.:*** *3.* ***Formulae:*** *5.* ***Bibl.:*** *16.*

Lukianenko Iryna H. *– Doctor of Science (Economics), Professor, Head of the Department, Department of Finance, National University of «Kyiv-Mohyla Academy» (vul. Skovorody, 2, 04655, Ukraine)*

Email: *luk@kse.org.ua*

Oliskevych Marianna O. *– Candidate of Sciences (Physics and Mathematics), Associate Professor, Associate Professor, Department of Mathematical Economics and Econometrics, Ivan Franko National University of Lviv (vul. Universytetska, 1, Lviv, 79000, Ukraine)*

Email: *olisk@ukr.net*

УДК 330.43/519.862/331.5

Лукьяненко И. Г., Олискевич М. А. Моделирование нелинейной динамики зарегистрированного уровня безработицы в Украине с помощью пороговых авторегрессий

В условиях нестабильности экономического развития национальной экономики анализ рынка труда и прогнозирования динамики уровня занятости и безработицы является важной составляющей для обеспечения социальной ответственности и уменьшения социальных рисков в обществе. Основной целью исследования является эмпирический анализ нелинейной динамики зарегистрированного уровня безработицы в Украине в условиях повышенных рисков и асимметричности информации, а также разработка соответствующего комплекса нелинейных пороговых авторегрессионных моделей. Методология исследования базируется на методах экономической теории и экономико-математическом инструментарии, в частности, использованы эконометрические методы анализа нелинейных временных рядов с нетипичными функциями распределения. В результате эмпирического исследования обосновано применение пороговых авторегрессионых моделей и оценен ряд нелинейных эконометрических спецификаций, которые позволяют объяснить асимметричную динамику безработицы. Полученная в результате эконометрического анализа пороговая функция и оцененное на основе реальной информации значение порогового параметра определяют разветвления TAR-модели на два разных режима поведения, которые по-разному характеризуют динамичный ход роста и снижения безработицы и позволяют в краткосрочном периоде предусматривать фазы спада и повышения занятости. Использование разработанных нелинейных эконометрических моделей динамики зарегистрированного уровня безработицы дополняет исследования характерных свойств, присущих сектору труда в Украине, и позволяет более точно прогнозировать последствия государственных мер в этой сфере. Установленный нелинейный характер динамики уровня безработицы свидетельствует о невальра-

УДК 330.43/519.862/331.5

Лук'яненко І. Г., Оліскевич М. О. Моделювання нелінійної динаміки зареєстрованого рівня безробіття в Україні за допомогою порогових авторегресій

В умовах нестабільності економічного розвитку національної економіки аналіз ринку праці та прогнозування динаміки рівня зайнятості та безробіття є важливою складовою для забезпечення соціальної відповідальності та зменшення соціальних ризиків у суспільстві. Основною метою дослідження є емпіричний аналіз нелінійної динаміки зареєстрованого рівня безробіття в Україні в умовах підвищених ризиків та асиметричності інформації, а також розробка відповідного комплексу нелінійних порогових авторегресійних моделей. Методологія дослідження базується на методах економічної теорії та економіко-математичному інструментарії, зокрема використано економетричні методи аналізу нелінійних часових рядів з нетиповими функціями розподілу. В результаті емпіричного дослідження обґрунтовано застосування порогових авторегресійних моделей і оцінено низку нелінійних економетричних специфікацій, які дають змогу пояснити асиметричну динаміку безробіття. Одержана внаслідок економетричного аналізу порогова функція й оцінене на основі реальної інформації значення порогового параметра визначають розгалуження TAR-моделі на два різні режими поведінки, які по-різному характеризують динамічний перебіг зростання та зниження безробіття і дають змогу в короткостроковому періоді передбачати фази спаду та підвищення зайнятості. Використання розроблених нелінійних економетричних моделей динаміки зареєстрованого рівня безробіття доповнює дослідження характерних властивостей, які притаманні сектору праці в Україні, та дозволяє більш точно прогнозувати наслідки державних заходів у цій сфері. Встановлений нелінійний характер динаміки рівня безробіття засвідчує невальрасівські властивості ринку праці в Україні та виявляє його нерівномірну й асиметричну циклічну поведінку.

совских свойствах рынка труда в Украине и свидетельствует о его неравномерном и асимметричном циклическом поведении.

***Ключевые слова:** безработица, занятость, авторегрессионная модель, TAR-модель, пороговый параметр, рынок труда*

***Рис.:** 2. **Табл.:** 3. **Формул:** 5. **Библ.:** 16.*

***Лукьяненко Ирина Григорьевна** – доктор экономических наук, профессор, заведующий кафедрой финансов, Национальный университет «Киево-Могилянская академия» (ул. Сковороды, 2, Киев, 04655, Украина)*

***Email:** luk@kse.org.ua*

***Олискевич Марианна Александровна** – кандидат физико-математических наук, доцент, доцент кафедры математической экономики и эконометрики, Львовский национальный университет имени И. Франко (ул. Університетська, 1, Львов, 79000, Украина)*

***Email:** olisk@ukr.net*

***Ключові слова:** безробіття, зайнятість, авторегресійна модель, TAR-модель, пороговий параметр, ринок праці*

***Рис.:** 2. **Табл.:** 3. **Формул:** 5. **Бібл.:** 16.*

***Лук'яненко Ірина Григорівна**– доктор економічних наук, професор, завідувач кафедри фінансів, Національний університет «Києво-Могилянська академія» (вул. Сковороди, 2, Київ, 04655, Україна)*

***Email:** luk@kse.org.ua*

***Оліскевич Маріанна Олександрівна** – кандидат фізико-математичних наук, доцент, доцент кафедри математичної економіки та економетрії, Львівський національний університет ім. І. Франка (вул. Університетська, 1, Львів, 79000, Україна)*

***Email:** olisk@ukr.net*

The processes of market transformation of the Ukrainian economy aimed at its socio-economic development, competitiveness and improvement of human capital level need deep theoretical and empiric research of labour market characteristics, as well as modelling and forecasting of its basic indicators tendencies, in particular unemployment and employment rate. The analysis and forecast of its tendencies change acquire special topicality in the modern conditions of economic development instability of the national economy, as it allows to forecast in advance the phases of employment and unemployment growth and fall and develop the corresponding measures of socio-economic policy aimed at social responsibility provision and social risks reduction in society. Nowadays the search of new approaches is very active, in particular those that are based on modern economic and mathematical tools that would give an opportunity to represent adequately difficult nonlinear processes and asymmetry of information that characterize labour market condition not only in Ukraine but also in other countries of the world. One of the perspective approaches in this direction is the approach that is based on application of econometric methods and models of analysis of nonlinear time series with the non-traditional functions of distribution, in particular models of threshold autoregressions. Consequently, the development and implementation of these models nowadays are of primary topicality for the research of labour market in Ukraine, since it will allow not only to forecast adequately nonlinear processes and change of their dynamics on the labour market but also to evaluate the values of threshold parameters, that determine different modes of their behaviour, in particular dynamics of unemployment and employment growth and fall that gives an opportunity in a short-term period to forecast the phases of their growth and fall and to react to them in time.

Fundamental principles of labour-market functioning and econometric modelling of its basic indicators both for the countries with market and transformation economy are highlighted in the works of the prominent western scientists G. Bardsen, O. Blanchard, C. Bean, J. Gali, B. Hansen, D. Peel, M. Peeters, A. Speight, etc. [1—5]. The results of their researches state that statistical data of labour-market indexes for different countries of the world have different properties that predetermine the necessity of search of non-traditional approaches to their empiric analysis and modelling. On the whole, nowadays the analysis and forecast of tendencies change of indicators of unemployment and employment on the different phases of economic cycle and evaluation of basic factors of unemployment in a long-term period remain one of the important directions of macroeconomic researches of western scientists. Thus, one of the actively investigated problems is a problem to what extent unemployment represents imperfection of market and what are the causes and effects of it [1; 2; 4].

Numerous works of domestic scientists are devoted to theoretical and empiric labour market research, in particular S. Babych, D. Bohynja, V. Fedorenko, O. Grishnova, L. Guryanova, T. Kiryan, T. Klebanova, O. Kolot, E. Libanova, I. Lukyanenko, L. Lysohor, K. Petrenko, T. Umanez', O. Yermolenko, etc [6—12]. Considerable contribution to the research of this range of problems is made by the scientists of Research Institute of Labour and Employment of Population of Ministry of Labour and Social Policy of Ukraine and The National Academy of Sciences of Ukraine [12]. Important direction of modern researches deals with the recurrence of short-term behaviour of labour-market. Some scientific theoretical and empiric results certify that a real salary is not cyclical as a result of non-Walrasian character of labour-market that determines its short-term behaviour [8, 11]. However, these researches haven't found a sufficient reflection in the works of the Ukrainian scientists. In addition, the problem of development and application of modern econometric methods and models for the analysis and forecast of nonlinear and asymmetric dynamics of employment and unemployment, in particular threshold autoregressions, inherent to the labour market of Ukraine are insufficiently investigated in the works of Ukrainian scientists [9]. Deepening of scientific researches in this direction will complement the analysis of characteristics, inherent to the labour market in Ukraine on the current stage of economic development and will allow more exactly and immediately to form government measures to reduce social tension in society.

In spite of sufficient number of researches of both western and Ukrainian scientists dedicated to the labour market and its basic indicators dynamics modelling, topical is the problem of improvement and development of different approaches to the construction of nonlinear econometric models of unemployment, the analysis of which would give an opportunity to control and forecast the possible tendencies changes on domestic labour market and form the corresponding measures of socio-economic policy.

The aim of the research is an empiric analysis of nonlinear dynamics of unemployment and employment rate in Ukraine in the conditions of increased risks and asymmetry of information, and also the development of corresponding complex of nonlinear threshold autoregressive models, justification of choosing threshold function-indicator, that will determine the change of the cyclic behaviour mode of the investigated indicator, quantitative evaluation of threshold parameter and forecast of tendencies changes of basic labour market indicators for forming appropriate socio-economic policy and program of social responsibility provision in Ukrainian society.

Theoretical dynamic models that determine common behaviour of employment of economic agent are based on maximization of the expected present value of his income

$$E\left[\sum_{t=0}^{\infty}\beta^t y_t\right],$$

where y_t – an income of economic agent (person) in a period *t*,

β – a discount factor $(0<\beta<1)$.

In case a person is unemployed and receives unemployment benefit *c,* his income is $y_t = c$*;* in case a person has accepted a job offer with wage w_t, that is a random variable with some distribution $F(w)=P\{W\le w\}$, then $y_t = w_t$.

Theoretical models of unemployment, in particular, the models of search and matching are based on the assumption, that an important characteristics of labour market is inconsistency between unemployed persons and vacancies, that they may apply for, and that is why the process of employment provision doesn't take place due to the market mechanisms, but is a result of difficult and lengthy process of matching search [13]. In such models a random parameter θ is introduced. It characterizes the level of consistency of parties and corresponds to marginal labour product. The process of matching search is divided into a few stages. During the first stage, when an unemployed person decides whether to accept a job offer, the value of θ is not observational, and a firm and a person are oriented only on value $y=\theta+u$, where u – a random noise that does not correlate with θ. It is assumed that $\theta \sim N[\mu,\sigma_0^2]$, $u \sim N[0,\sigma_u^2]$. If a person has accepted a job offer and begins to work, then during the next stage in the process of collaboration a firm and worker gradually examine each other, set a corresponding wage level that is determined by the formula $m_0 = E[\theta/(\theta+u)] = \mu+\sigma_0^2/(\sigma_0^2+\sigma_u^2)\cdot(y-\mu)$.

During the third stage parties decide whether to contract and work further on these terms or an employee resigns from the job and looks for a new one responding or not to other job offers. Generally the implementation of such model is conducted by Bellman principle and results in the following equation during the second stage

$$V(m_0)=\max\{m_0+\beta\int J(\theta')dF(\theta'|m_0,\sigma_1^2),\beta Q\},$$

where $J(\theta)$ – a solution of Bellman equation $J(\theta) = \max\{\theta+\beta J(\theta),\beta Q\}$, obtained during the third stage $\sigma_1^2=\sigma_0^2/(\sigma_0^2+\sigma_u^2)\cdot\sigma_u^2$,

Q – expected present value of wage of a person, who is unemployed and behaves optimally.

Theoretical conclusions of research of search and matching models while studying unemployment confirm statistical observations that characterize labour market and show that the wage grows with the increase of duration of worker and firm collaboration, quits usually happens at the initial stages of such collaboration, and also, that the sequence of quits negatively correlates with the current growth rate of wage. Thus, the theoretical models of unemployment certify non-linearity and asymmetry of fluctuations on the labour market that causes different character of dynamics of unemployment rate in periods of its increase and gradual decline.

On the basis of theoretical implications of non-linearity of labour market indexes behaviour, we will model the dynamics of unemployment rate for the Ukrainian economy by means of analysis of nonlinear time series. We will consider a time series that describes a registered unemployment rate among working population in Ukraine. Dynamics of its monthly values during January 2000 – June 2015 is presented on Fig.1*a*. The data have been obtained on the basis of the statistical reports on the web-site of State Statistics Service of Ukraine and periodicals of *State Employment Centre of Ukraine* [14]. Visual analysis of the graph of this time series allows making a preliminary conclusion about its non-stationarity. Statistical testing of this time series for a unit root on the basis of the augmented Dickey–Fuller test (ADF = –0.8649) confirms, that the time series u_t, that we are analysing, is integrated of first order, and that is why we will conduct modelling for the row of the first differences, that correspondingly is stationary. The graph of values of the first-order differences of the row is presented on Fig. 1*b*.

Investigating statistical properties and graphic presentation of values of unemployment rate in Ukraine, it is possible to assume that its behaviour is modelled by different processes during different time intervals. To model such type of non-linearity threshold autoregressive models are applied [5; 15; 16]. They give an opportunity to represent the change of behaviour of time series depending on the value of some function that is determined by the economic structure. One of the most widespread types of this class of models is a two-regime threshold autoregressive model (TAR) of unemployment of a standard form:

$$\begin{aligned}\Delta u_t &= (\alpha_0+\alpha_1\Delta u_{t-1}+\alpha_2\Delta u_{t-2}+\ldots+\alpha_p\Delta u_{t-p})\cdot I(q_{t-1}\le\gamma)+\\ &+(\beta_0+\beta_1\Delta u_{t-1}+\beta_2\Delta u_{t-2}+\ldots+\beta_p\Delta u_{t-p})\cdot I(q_{t-1}>\gamma)+\varepsilon_t,\end{aligned} \quad (1)$$

where $I(\cdot)$ denotes a function – indicator, $q_{t-1}=q(u_{t-1},\ldots,u_{t-p})$ is a known data function. The value of parameter $p>1$ determines the order of autoregression. A parameter γ is called a threshold parameter. Parameters α_j are the autoregressive slope coefficients for $q_{t-1}\le\gamma$, and parameters β_j are autoregressive coefficients for lagged variables for $q_{t-1}>\gamma$. It is assumed that error ε_t are equally distributed independent random values (ε_t is idd $[0,\sigma^2]$).

Having defined $y_t=(1 \quad \Delta u_{t-1} \quad \ldots \quad \Delta u_{t-p})'$ and

$$y_t(\gamma)=(y'_t\cdot I(q_{t-1}\le\gamma) \quad y'_t\cdot I(q_{t-1}>\gamma))'.$$

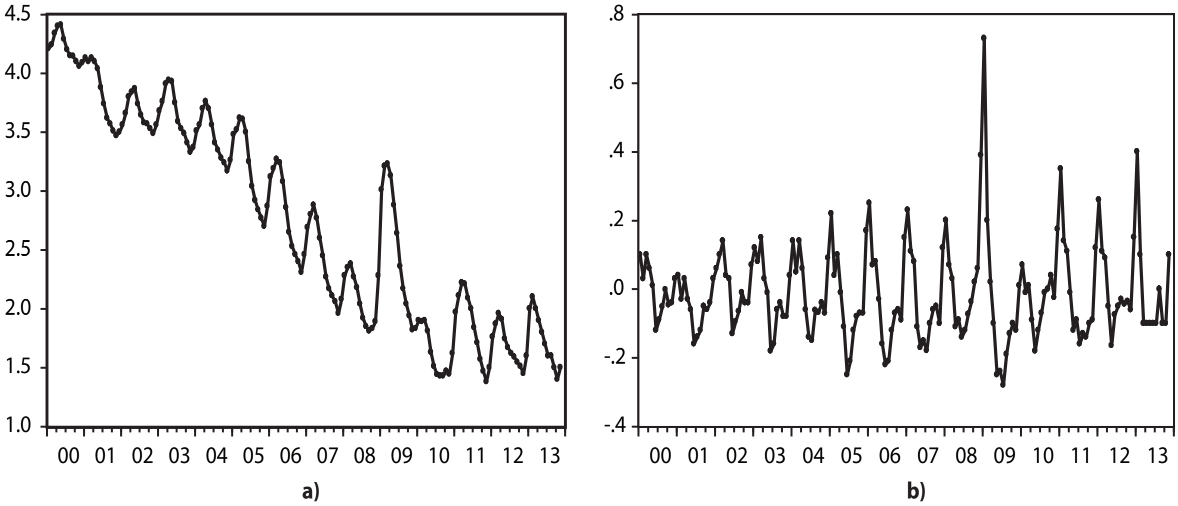

Fig. 1: a) Dynamics of unemployment rate in Ukraine during 2000–2015;
b) Dynamics of changes in unemployment rate in Ukraine during 2000–2015

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

The model (1) can be written in an alternative form [14]:

$$\Delta u_t = y'_t \cdot \alpha \cdot I(q_{t-1} \le \gamma) + y'_t \cdot \beta \cdot I(q_{t-1} > \gamma) + \varepsilon_t$$

or

$$\Delta u_t = y'_t(\gamma) \cdot \delta + \varepsilon_t, \qquad (2)$$

where $\delta = (\alpha' \quad \beta')'$.

The unknown parameters of model (2) that need to be estimated, are δ and γ, and since it is nonlinear in relation to parameters, one of adequate methods of evaluation is a maximum likelihood method (ML). By assumption that ε_t is idd $N[0,\sigma^2]$, ML is equivalent to the least square method (LS). Taking into account that regression equation (2) is discontinuous, it is appropriate to use sequential conditional LS values for the evaluation of model parameters.

For a given value of γ we obtain LS estimate of δ as [16]:

$$\hat{\delta}(\gamma) = \left(\sum_{t=1}^{T} y_t(\gamma) y'_t(\gamma) \right)^{-1} \left(\sum_{t=1}^{T} y_t(\gamma) \Delta u_t \right).$$

On the basis of residuals of estimated model

$$\hat{\varepsilon}_t(\gamma) = \Delta u_t - y'_t(\gamma)\hat{\delta}(\gamma)$$

we calculate the estimate of the variation of the unexplained part of the regression

$$\hat{\sigma}_T^2(\gamma) = \frac{1}{T} \sum_{t=1}^{T} (\hat{\varepsilon}_t(\gamma))^2. \qquad (3)$$

Then LS estimate of threshold parameter γ is a value that minimizes variance (3)

$$\hat{\gamma} = \operatorname{argmin}_{\gamma \in \Gamma} \hat{\sigma}_T^2(\gamma)$$

where $q_{t-1} \in \Gamma = [\gamma_1, \gamma_2]$.

It should be noted that variance of residuals $\hat{\sigma}_T^2(\gamma)$ can acquire maximum T of different values that depend on values that a parameter γ is varied. These values correspond to $\hat{\sigma}_T^2(q_{t-1})$, $t = 1, \ldots, T$. Therefore, we will apply OLS to regressions of type (2), accepting that $\gamma = q_{t-1}$ for each $q_{t-1} \in \Gamma$ to estimate model parameters. For every regression we calculate residual variance and choose a value γ that corresponds to the lowest value of variance, i.e.

$$\hat{\gamma} = \operatorname{argmin}_{q \in \Gamma} \hat{\sigma}_T^2(q_{t-1}).$$

Then we find estimate $\hat{\delta}$ as $\hat{\delta} = \hat{\delta}(\hat{\gamma})$. Corresponding residuals we calculate as $\hat{\varepsilon}_t = \Delta u_t - (y_t(\hat{\gamma}))'\hat{\delta}$ with sampling variance $\hat{\sigma}_T^2 = \hat{\sigma}_T^2(\hat{\gamma})$.

For application of threshold model in the research of the behaviour of unemployment rate as a function – indicator we will consider different lags of changes of unemployment Δu_{t-d} for some $d \le 12$, and also different lags of unemployment rates. Tables 1 and 2 present results of models estimation that take into account 24 different variants of threshold functions. Numeral calculations have been conducted on the basis of the program created by us in the software environment of GAUSS by means of matrix programming language, that is widely used by scientists, statisticians, econometrists and by financial analysts and is universal enough for various numeral tasks. The first column of tables presents the type of threshold function. The second – a minimum sum of squares of residuals for a corresponding threshold function. The best result in case of the use of delays of unemployment change (see Table 1) we have obtained for $q_{t-1} = \Delta u_{t-6}$, and in case of the use of unemployment lags (see Table 2) – for $q_{t-1} = u_{t-2}$.

It is important to check whether the developed nonlinear TAR models statistically significantly differ from the linear autoregressive models of certain order that is determined in the process of analysis of graphs of autocorrelation and partly autocorrelation function, and also more difficult procedures. A corresponding null hypothesis is H_0: $\alpha = \beta$. If errors are independent and equally distributed, then on condition of the known value of threshold, testing of null hypothesis with a test power that is close to optimal, is possible to carry out, using F-statistics [16]

Table 1

Search and testing results of overall significance of TAR models of unemployment for a threshold function that characterizes lags of changes in an unemployment rate

Type of threshold function	The lowest value of variance $\hat{\sigma}_T^2 * 1000$	Estimation of threshold parameter $\hat{\gamma}$	Testing of significance of TAR model $F_T(\gamma)$	Probability of inadequacy of TAR model *Prob*
$q_{t-1} = \Delta u_{t-1}$	3.8187	0.065	80.24	0.000
$q_{t-1} = \Delta u_{t-2}$	3.8493	0.005	78.36	0.000
$q_{t-1} = \Delta u_{t-3}$	3.9610	-0.035	71.75	0.001
$q_{t-1} = \Delta u_{t-4}$	3.8030	0.005	81.22	0.000
$q_{t-1} = \Delta u_{t-5}$	4.2664	-0.073	55.44	0.001
$q_{t-1} = \Delta u_{t-6}$	3.2135	-0.105	124.73	0.000
$q_{t-1} = \Delta u_{t-7}$	3.6485	-0.125	91.26	0.000
$q_{t-1} = \Delta u_{t-8}$	3.7097	-0.085	87.18	0.000
$q_{t-1} = \Delta u_{t-9}$	3.8647	-0.098	77.42	0.000
$q_{t-1} = \Delta u_{t-10}$	3.6432	0.006	91.27	0.000
$q_{t-1} = \Delta u_{t-11}$	3.6134	0.045	93.62	0.000
$q_{t-1} = \Delta u_{t-12}$	3.3641	0.105	112.15	0.000

Source: estimations of authors

Table 2

Search and testing results of overall significance of TAR models of unemployment for a threshold function that characterizes lags of unemployment rate

Type of threshold function	The lowest value of variance $\hat{\sigma}_T^2 * 1000$	Estimation of threshold parameter $\hat{\gamma}$	Testing of significance of TAR model $F_T(\gamma)$	Probability of inadequacy of TAR model *Prob*
$q_{t-1} = \Delta u_{t-1}$	3.3183	2.296	115.86	0.000
$q_{t-1} = \Delta u_{t-2}$	3.2383	2.050	131.82	0.000
$q_{t-1} = \Delta u_{t-3}$	3.5030	1.835	101.52	0.000
$q_{t-1} = \Delta u_{t-4}$	4.1370	2.175	62.06	0.000
$q_{t-1} = \Delta u_{t-5}$	4.3347	2.390	52.11	0.006
$q_{t-1} = \Delta u_{t-6}$	4.4971	2.493	44.60	0.019
$q_{t-1} = \Delta u_{t-7}$	4.5074	2.645	44.13	0.029
$q_{t-1} = \Delta u_{t-8}$	4.5414	3.150	42.64	0.040
$q_{t-1} = \Delta u_{t-9}$	4.6584	3.154	37.65	0.099
$q_{t-1} = \Delta u_{t-10}$	4.2658	2.427	39.01	0.081
$q_{t-1} = \Delta u_{t-11}$	4.0201	2.370	68.40	0.000
$q_{t-1} = \Delta u_{t-12}$	3.9001	2.335	75.31	0.000

Source: estimations of authors

$$F_T(\gamma) = T((\sigma_a)_T^2 - \hat{\sigma}_T^2(\gamma)) / (\hat{\sigma}_T^2(\gamma)), \qquad (4)$$

where

$$(\sigma_a)_T^2 = 1/T \sum_{t=1}^{T} (\Delta u_t - y'_t a)^2,$$

and

$$a = \left(\sum_{t=1}^{T} y_t y'_t \right)^{-1} \left(\sum_{t=1}^{T} y_t \Delta u_t \right)$$

is OLS evaluation α by assumption that $\alpha = \beta$. Since $F_T(\gamma)$ is monotonous of $\hat{\sigma}_T^2$ function, then

$$F_T = \sup_{\gamma \in \Gamma} F_T(\gamma)$$

is point F - statistics against the alternative $H_1: \alpha \neq \beta$ if γ is known.

However, for TAR model such testing is not correct, since a threshold γ is not defined for H_0 and asymptotic distribution F_T in this case is not chi-square distribution. Methodology of testing of hypothesis H_0 for TAR models has been proposed by Hansen [16]. He showed that asymptotic distribution can be approximated by means of such bootstrap procedure.

Let e_t^* is idd $N[0,1]$ $(t = 1, \ldots, T)$ random draws. We will estimate regression e_t^* on y_t to obtain residual variance $(\sigma_a^*)_T^2$, and on $y_t(\gamma)$ to obtain residual variance $(\hat{\sigma}^*)_T^2(\gamma)$. Then $F_T^*(\gamma) = T((\sigma_a^*)_T^2 - (\hat{\sigma}^*)_T^2(\gamma)) / ((\hat{\sigma}^*)_T^2(\gamma))$ and $F_T^* = \sup_{\gamma \in \Gamma} F_T^*(\gamma)$. Distribution F_T^* converges weakly in probability to distribution F_T^*, thus the repetition of bootstrap procedure for F_T^* can be used for approximation of asymptotic distribution F_T. Bootstrap approximation of test *p*-value is formed on the basis of calculation of sample percent, for which F_T^* exceeds F_T.

We will conduct the procedure of adequacy testing of TAR model (2) for different variants of threshold functions for which the point estimations of parameters and corresponding residual variances have already been calculated. We will also calculate p - values, that determine probability that AR model has advantage over the corresponding TAR model. Values of F-statistics and corresponding probabilities (Prob) for 24 threshold functions are presented in the last two columns of Tables 1 and 2. Testing results certify that in most cases we haven't obtained statistically meaningful residuals that would show that unemployment rate modelling by means of linear AR-model is more adequate, than nonlinear TAR modelling.

The results of calculations show that unemployment has a nonlinear structure and while modelling its behaviour it is necessary to apply threshold models that give an opportunity to represent its different dynamics depending on the previous state of economic environment. In particular, it has been revealed that the behaviour change of unemployment takes place when its value two periods ago exceeded 2.05, or when unemployment change half a year ago was more than –0.105. In this respect the influence on the mode of behaviour of past values of unemployment changes is more significant than the influence of past values of unemployment rate.

The general specification of the evaluated nonlinear threshold autoregressive model of unemployment is:

$$\Delta u_t = (\alpha_0 + \alpha_1 \Delta u_{t-1} + \alpha_2 \Delta u_{t-2} + \ldots + \alpha_p \Delta u_{t-12}) I(\Delta u_{t-6} \leq -0{,}105) + \\ +(\beta_0 + \beta_1 \Delta u_{t-1} + \beta_2 \Delta u_{t-2} + \ldots + \beta_p \Delta u_{t-12}) I(\Delta u_{t-6} > -0{,}105) + \varepsilon_t, \quad (5)$$

The values of evaluations of parameters of model (5) and their corresponding *t*-statistics are presented in Table 3. The values of Student's statistics state that most parameters are statistically significant.

Table 3

Parameter estimations and significance testing results of nonlinear threshold autoregressive model of unemployment

Lag order j	Estimates of parameters α_j	Student's statistics $t(\alpha_j)$	Estimates of parameters β_j	Student's statistics $t(\beta_j)$
1	0.1304	2.5146*	-0.0138	-2.2971*
2	1.4076	9.3539**	0.3652	5.1405**
3	-1.2280	-5.0466**	-1.0824	-4.0247**
4	1.4460	5.2121**	-0.0312	-0.4108
5	0.2589	0.7058	-0.1720	-2.3482*
6	-0.8418	-2.1706*	0.0087	0.1172
7	1.1212	2.7584**	-0.1055	-1.3039
8	-0.2693	-1.0601	-0.0554	-0.7043
9	-0.5451	-2.1977*	-0.0134	-0.1633
10	0.9135	4.5120**	-0.1956	-2.1120*
11	-0.2866	-1.8516	0.1088	0.9256
12	0.2769	2.2000*	0.0715	0.6464

Source: estimations of authors

Threshold function defined on the basis of modelling and estimation of threshold parameter show that a model will change its regime when the unemployment rate change, that happened half a year ago, will exceed a value of - 0,105. Using point estimates of slope parameters and threshold parameter, we will find estimated values of unemployment rate in Ukraine. Fig. 2 presents the estimated values of unemployment rate in Ukraine by means of constructed TAR model. The observations that are described by the different branches of threshold autoregression are presented by different symbols.

Modelling results state that during the investigated period 49 observations in the different months of different years are governed by the first regime and characterize the periods of unemployment growth, while 142 observations belong to the

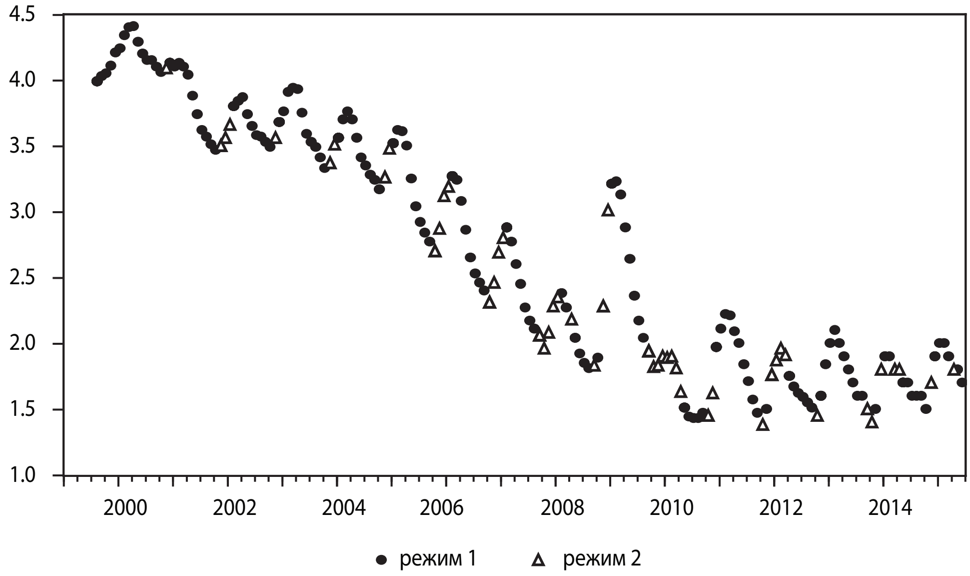

Fig. 2. Branching unemployment rates into two different regimes of behaviour depending on the change of past values

Source: evaluations of authors

second regime of behaviour that describes the dynamics of employment growth respectively.

Conclusions. As a result of empiric research the row of nonlinear econometric specifications has been estimated and application of threshold autoregressive model for description of nonlinear and asymmetric behaviour of unemployment rate in Ukraine has been justified. Modelling states that the dynamics of unemployment rate in the national economy is characterized by different regimes of behaviour that change depending on the value acquired by the threshold function that is defined by econometric analysis. The estimated value of threshold parameter reveals branching of TAR model behaviour of unemployment rate in two directions, and transition between them is determined by the fact whether unemployment rate change, that was observed 6 months ago was higher than –0,105, or not. The first branch of developed nonlinear autoregression describes and gives an opportunity in a short-term period to forecast the dynamics of unemployment rate growth, and consequently and employment reduction, while the second set of estimations allows to characterise dynamics of unemployment fall and to forecast employment growth phases. The revealed nonlinear character of unemployment rate dynamics confirms non-Walrasian properties of labour market in Ukraine and states its uneven and asymmetric cyclic behaviour.

The research showed that development and application of threshold autoregressive models is a perspective direction of nonlinear character and tendencies changes of basic labour market indicators forecast, since it allows to obtain not only qualitative forecasts, but also to evaluate quantitatively the values of threshold parameters, that determine the different modes of their behaviour that gives an opportunity in advance to forecast the phases of their fall and growth and to react to them in time. Further directions of researches are development and estimation of the real information of more difficult modifications of threshold autoregressions with more than one threshold parameter.

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