# АКТУАЛЬНІ ПРОБЛЕМИ ПРОГНОЗУВАННЯ РОЗВИТКУ СОЦІАЛЬНО-ЕКОНОМІЧНИХ СИСТЕМ

КИЇВСЬКИЙ НАЦІОНАЛЬНИЙ УНІВЕРСИТЕТ ІМЕНІ ТАРАСА ШЕВЧЕНКА

БЕРДЯНСЬКИЙ ДЕРЖАВНИЙ ПЕДАГОГІЧНИЙ УНІВЕРСИТЕТ

ДУ «ІНСТИТУТ ЕКОНОМІКИ І ПРОГНОЗУВАННЯ НАН УКРАЇНИ»

КИЇВСЬКИЙ НАЦІОНАЛЬНИЙ ЕКОНОМІЧНИЙ УНІВЕРСИТЕТ ІМЕНІ В. ГЕТЬМАНА

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# АКТУАЛЬНІ ПРОБЛЕМИ ПРОГНОЗУВАННЯ РОЗВИТКУ СОЦІАЛЬНО-ЕКОНОМІЧНИХ СИСТЕМ

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А43    **Актуальні проблеми прогнозування розвитку соціально-економічних систем:** Монографія / За ред. О.І. Черняка, П.В. Захарченка. – Мелітополь: Видавничий будинок Мелітопольської міської друкарні 2019. - 456 с., Англ. мова, польск. мова, рос. мова, укр. мова.

У монографії розглядаються актуальні проблеми прогнозування розвитку соціально-економічних систем. Обґрунтовуються математичні методи мікроекономічного та макроекономічного прогнозування, здійснено оцінювання трудової міграції з України до країн Північної Америки та Європейського Союзу за допомогою гравітаційних моделей, проведено математичне моделювання індексів фондового ринку, представлено комплекс моделей аналізу динаміки розвитку фіскального федералізму. Розроблено систему прогнозування впливу інфляції на економічну поведінку домогосподарств України, запропоновано сучасні методи в дослідженні безпеки економічних систем, розроблено комплекс моделей для прогнозування розподілу та використання бюджетних коштів на програми розвитку Збройних Сил України в умовах економічної нестабільності, тощо. Окремо увагу приділено питанням економічного прогнозування та управління курортними рекреаціями і туризмом в регіонах України. Для фахівців в області моделювання, прогнозування, та управління складними соціально-економічними системами, а також викладачів, аспірантів і студентів економічних спеціальностей

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### 1.16. Levy Distribution Parameters as Precursors of Crisis Phenomena

### 1 Introduction

With a rapidly growing financial market, new risk management methods are becoming more demanded that take into account new non-Gaussian distributions. The task of monitoring and predicting of possible critical states of financial and economics systems are very relevant today. In our opinion, the availability of the time series for stock markets gives the opportunity to solve such tasks in very effective ways. Financial crises that regularly shake the world economy are characterized by noticeable fluctuations in stock indices, thereby causing noticeable changes in the statistical distributions of empirical data [1, 2].

Gold has been an important precious metal for many centuries, and plays a special role as a store of value especially in times with political and economic uncertainties. Hence, compared with other metals in the large commodity market, gold registers an evident advantage and outstanding position. In recent years, because of the nice profit-making situation and remarkable risk-avoidance feature, gold market has seen a very active picture. As a result, the role of gold market in the large commodity market even in the whole social economy has received increasing attention by both academia and industrial cycles, and research concerned also can be found emerging.

In the wake of global industrialization and marketoriented process, crude oil futures, as the largest commodity futures in the world, has a profound influence on other futures. For instance, due to the rapid development of alternative energy, America uses a great deal of corn and white sugar to produce bioethanol and employs soybean to generate biodiesel oil; as a result, there can be seen a close relation between the crude oil price and the prices of grease products, soybean and corns. Additionally, given the extensive usage, the crude oil has become one of the most important and fundamental lifelines of global economy, and its price is supposed to be of great significance to the prices of other commodities.

Consequently, the analysis of the form and parameters of the distribution of price fluctuations of the stock market indexes, gold market and crude oil will make it possible to predict the possible occurrence of the financial crisis.

In 1900, Bachelier proposed the first model for the stochastic process of returns - an uncorrelated random walk with independent, identically Gaussian distributed (i.i.d) random variables [3]. This model is natural if one considers the return over a time scale $\Delta t$ to be the result of many independent "shocks", which then lead by the central limit theorem to a Gaussian distribution of returns [3]. However, empirical studies [4-6] show that the distribution of returns has pronounced tails in striking contrast to that of a Gaussian.

For time series $S(t)$ which describes the dynamics of price on stock index, the returns $g(t)$ over some time scale $\Delta t$ is defined as the forward changes in the logarithm of $S(t)$,

$$g(t) \equiv (\ln S(t + \Delta t) / \ln S(t)). \qquad (1)$$

For small changes in the price, the returns $g(t)$ is approximately the forward relative change

$$g(t) \approx \frac{S(t + \Delta t) - S(t)}{S(t)}. \qquad (2)$$

To illustrate mentioned above fact, we show in Fig. 1 the daily returns of the DJIA index for 1900-2019 and contrast it with a sequence of i.i.d. Gaussian random variables.
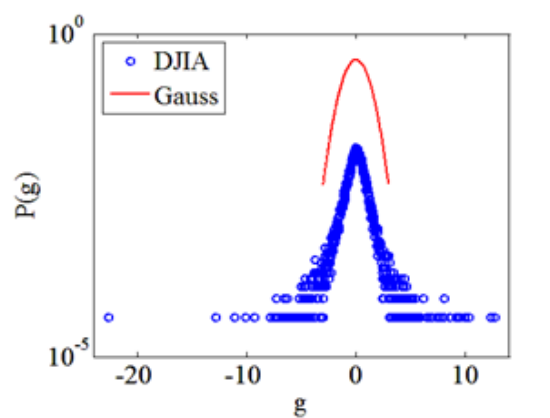


**Fig. 1.** Probability density function of DJIA daily normalized returns during the period from 1900 to 2019

It is obvious that the distribution of returns has heavy tails and in the general case can be described as

$$P(g > x): \ x^{-(1+\alpha)}, \quad \alpha \in (0,2] \tag{3}$$

and for stock indexes it has a universal look, known as the cubic laws of stock market activity [6].

Fig. 2 confirms the cubic law for the DJIA index.
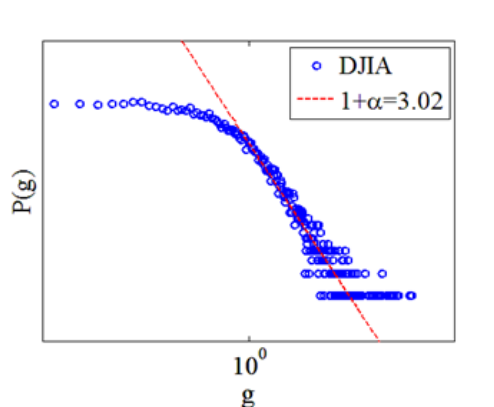


**Fig. 2.** Cumulative distributions of the normalized DJIA daily returns. Fits yield values $\alpha = 2.02 \pm 0.02$

In the analysis of cotton prices, Mandelbrot observed that in addition to being non-Gaussian, the process of returns shows another interesting property: "time

scaling" — that is, the distributions of returns for various choices of Δt, ranging from 1 day up to 1 month have similar functional forms [7]. Motivated by (i) pronounced tails, and (ii) a stable functional form for different time scales, Mandelbrot [7] proposed that the distribution of returns is consistent with a Levy stable distribution [8] — that is, the returns can be modeled as a Levy stable process. Levy stable distributions arise from the generalization of the Central Limit Theorem (CLT) to random variables which do not have a finite second moment.

The CLT [9], which offers the fundamental justification for approximate normality, points to the importance of $\alpha$-stable distribution: they are the only limiting laws of normalized sums of independent, identically distributed random variables. Gaussian distributions, the best known member of the stable family, have long been well understood and widely used in all sorts of problems. However, they do not allow for large fluctuations and are thus inadequate for modeling high variability. Non-Gaussian stable models, on other hand, do not share such limitations. In general, the upper and lower tails of their distributions decreases like a power function. In literature, this is often characterized as heavy or long tails. In the last two or three decades, data which seem to fit the stable model has been collected in fields as diverse as economics, telecommunications, hydrology and physics (see for example [6]).

During our research of Levy's stable distribution, applied for the stock market, Brent crude oil and for the gold market, we have found that there are many articles, which were devoted to it [4-6, 10-12]. Consequently, it was pointed out that Levy's stable distribution fits better that the Gaussian distribution to financial and spot markets. It is still debatable whether Levy's stable distribution is appreciable, since there is not enough theoretical material and there is not a universal analyzing method for estimating parameters of Levy's stable distribution.

Therefore, during our research we discuss theoretical material applied to Levy's stable distribution, and discuss whether it acceptable for indicating crisis states on financial markets or not.

Our research structured as follows. Section 2 is introduction to Levy's stable distribution and its properties. Section 3 describes different approaches for estimating stable distribution parameters. In Section 4 we described how to estimate Levy's stable distribution and which method the most appreciable method for calculating its parameters. Section 5 present classified DJIA, gold and Brent crude oil price data and obtained results.

## 2 Levy's stable distribution properties

Levy's stable distribution being the generalization of the CLT, became an addition to a wide class of distributions. Assume that $P_n \equiv \sum_{i=1}^{n} x_i$ is the sum of i.i.d. random variables $x_i$. Then, if the variables $x_i$ have finite second moment, the CLT holds and $P_n$ is distributed as a Gaussian in the limit $n \to \infty$.

In case when the random variables $x_i$ are characterized by a distribution having asymptotic power-law behavior (3) $P_n$ will converge to a Levy stable stochastic process of index $\alpha$ in the limit $n \to \infty$.

Stable distribution is presented by 4 parameters: $\alpha \in (0,2]$ is the stability parameter, $\beta \in [-1,1]$ the skewness parameter, $\gamma \in [0,\infty)$ the scale parameter and $\delta \in (-\infty,\infty)$ the location parameter. Since the variables $x_i$ is characterized by four parameters, we will denote $\alpha$-stable distribution by $S(\alpha,\beta,\gamma,\delta)$ and write

$$x : S(\alpha,\beta,\gamma,\delta). \tag{4}$$

Stable distribution has a property that the mean cannot be defined for $\alpha \in (0,1]$ and the variance diverges for $\alpha \in (0,2)$.

Furthermore, the Levy stable distributions cannot be defined in closed form for a few cases: the case of $(\alpha,\beta) = (2,0)$ corresponds to the Gaussian distribution, $(\alpha,\beta) = (1,0)$ to the Cauchy distribution Instead, it is expressed in terms of their Fourier transforms or characteristic functions (CF), which we denote as $\lambda(k)$, where $k$ denotes the Fourier transformed variable.

For Levy stable distribution, if the variable $x_i$ follows $S(\alpha,\beta,\gamma,\delta)$, the CF can be expressed as [13]

$$\lambda(k) = \begin{cases} \exp\{i\delta k - |\gamma k|^{\alpha} [1 + i\beta \dfrac{k}{|k|} tg(\dfrac{\pi\alpha}{2})]\}, & (\alpha \neq 1) \\ \exp\{i\delta k - |\gamma k|^{\alpha} [1 + i\beta \dfrac{k}{|k|} \ln|k|]\}, & (\alpha = 1) \end{cases}. \tag{5}$$

It worth considering that with value of $\beta = 0$, the distribution is symmetric, right-tailed if positive, and left-tailed if negative.

## 3 Methods for estimation of stable law parameters

There are numerous approaches which can estimate stable distribution parameters. Since the probability density functions are not always expressed in a closed form, there are some challenges to overcome the analytic difficulties. Thus, there have been constructed a variety of methods: the approximate maximum likelihood estimation [14, 15], quantiles method [16, 17], fractional lower order

moment method [18, 19], method of log-cumulant [20], the logarithmic moment method [21] and more. Unfortunately, some of those methods cannot be applied due to computational problems associated with limited range of estimation, restricted range of parameters, high computational costs, or requiring large number of data. However, several of them should be mentioned.

### 3.1 Maximum Likelihood Method

DuMouchel was the first to obtain approximate ML estimates of $\alpha$ and $\gamma$ (assuming $\delta = 0$) [22]. A multinomial approximation to the likelihood function is used in his approach. Under some additional assumptions on $\hat{\alpha}$ and the likelihood function, DuMouchel has shown the obtained estimates to be consistent and asymptotically normal. However, the computational effort involved seems considerable.

A direct method can be formulated, after Brorsen and Yang [14], as follows. The standard symmetric probability density functions defined by Zolotariev [23] is presented as

$$f_{\alpha}(x) = \frac{\alpha}{\pi|1-\alpha|} x^{1/(\alpha-1)} \int_0^{\pi/2} U_{\alpha}(\eta,0)e^{-x^{\alpha/(\alpha-1)U_{\alpha}(\eta,0)}} d\eta, \tag{6}$$

for $\alpha \neq 1, x > 0$, where $U_{\alpha}$ is defined by

$$U_{\alpha}(\eta,\eta_0) = \left(\frac{\sin\alpha(\eta-\eta_0)}{\cos\eta}\right)^{\alpha/(1-\alpha)} \frac{\cos(\eta-\alpha(\eta-\eta_0))}{\cos\eta}, \tag{7}$$

and $\eta_0$ is explained here [24]. Therefore, the parameters $\alpha, \gamma$ and $\delta$ can be estimated from the observations $x_i (i = 1, 2, \ldots n)$ by maximizing the log likelihood function

$$\sum_{i=1}^{n} \log f_{\alpha}(z_i) = n\log\alpha - n\log(\alpha-1)\pi$$

$$+ \sum_{i=1}^{n} \frac{\log z_i}{\alpha-1}$$

$$+ \sum_{i=1}^{n} \log \int_0^{\pi/2} U_{\alpha}(\eta,0)e^{-z_i^{\alpha/(\alpha-1)}U_{\alpha}(\eta,0)} d\eta, \tag{8}$$

where $z_i = |x_i - \delta| / \gamma$.

To avoid the discontinuity and nondifferentiability of the symmetric $\alpha$-stable density function at $\alpha = 1$, $\alpha$ is restricted to be greater than one. Caution must be used when evaluating the integrals (6) and (8), since the integrals are singular at $\eta = 0$.

An obvious disadvantage of this method is that it is a highly nonlinear optimization problem and no initialization and convergence analysis is available.

## 3.2 Sample Quantiles Methods

Let $x_f$ be the $f$-th population *quantile*, so that $S(\alpha, \beta, \gamma, \delta)(x_f) = f$. Let $\hat{x}_f$ be the corresponding *sample quantile*, i.e. $\hat{x}_f$ satisfies $F_n(\hat{x}_f) = f$. As McCulloch [17] points out, to avoid spurious skewness in finite samples, a correction must be made. If the $x_i$'s are arranged in ascending order, the correction may be performed by identifying $x_i$ with $\hat{x}_{q(i)}$, where $q(i) = \dfrac{2i-1}{2n}$, and then interpolating linearly from the two adjacent $q(i)$ values to $f$. Then $\hat{x}_f$ is a consistent estimator of $x_f$, the $f$ quantile.

## 3.3 Regression Method

Koutrouvelis [13, 25] presented a regression type method of estimating the four parameters of stable distribution. It is based on the following algorithm concerning the CF. From (5) it can be derived that

$$\log(-\log|\lambda(k)|^2) = \log(2\gamma^\alpha) + \alpha \log|k|. \tag{9}$$

The real and imaginary parts of $\lambda(k)$ are for $\alpha \neq 1$ given by

$$\lambda_R(k) = \exp(-|\gamma k|^\alpha)\cos\left[\delta k + |\gamma k|^\alpha \beta sign(t) tg\left(\frac{\pi\alpha}{2}\right)\right],$$

and

$$\lambda_I(k) = \exp(-|\gamma k|^\alpha)\sin\left[\delta k + |\gamma k|^\alpha \beta sign(t) tg\left(\frac{\pi\alpha}{2}\right)\right].$$

The last two equations lead, apart from considerations of principal values, to

$$arctg\left(\frac{\lambda_I(k)}{\lambda_R(k)}\right) = \delta k + \beta\gamma^\alpha tg\left(\frac{\pi\alpha}{2}\right)sign(k)|k|^\alpha. \tag{10}$$

Equation (9) depends only on $\alpha$ and $\gamma$ and suggests that we estimate these parameters by regressing

$$y = \log\left(-\log|\lambda_N(k)|^2\right)$$

on $\omega = \log|k|$ in the model

$$y_n = m + \alpha\omega_n + \varepsilon_n, \quad n = 1, 2, \ldots, N, \tag{11}$$

where $(k_n)$ is an appropriate set of real numbers, $m = \log(2\gamma^\alpha)$, and $\varepsilon_n$ responds for an error term.

With estimated and fixed parameters $\alpha$ and $\gamma$, the values of $\beta$ and $\delta$ can be obtained by using equation (9). Let $g_n(u) = Arctg(\lambda_{\mathrm{I},n} / \lambda_{\mathrm{R},n})$, where $Arctg$ denotes the principal value of the arctan function. Then we can estimate $\beta$ and $\delta$ by regressing $z = g_n(u) + \pi \tau_n(u)$ on $u$ and $sign(u)|u|^{\alpha}$ in the model

$$z_l = \delta u_l + \beta \gamma^{\alpha} tg\left(\frac{\pi\alpha}{2}\right) sign(u_l)|u_l|^{\alpha} + v_l, l = 1, \ldots, L, \qquad (12)$$

where $(u_l)$ is an appropriate set of real numbers and $v_l$ denotes an error term.

As it was mentioned before, most of these methods have high computational costs, restricted ranges of parameters or require a large number of data. Thus, we would like to use simple approach proposed by Koutrovelis [25] which is based on CF and it is tested to be valid and clears the above issues.

## 4 Estimation of Levy's stable distribution

When we analyze data, we often assume that they are *ergodic* [26]. In general, if random variables $x_n (n = 1, 2, \ldots N)$ are ergodic with the integrable function $f(x)$, the preserving map $T(x)$ and the measure $p(x)dx$ in the space $M$, then the following equation holds [27]:

$$\lim_{N \to \infty} \frac{1}{N} \sum_{n=1}^{N} f(T^n x) = \int_{M} f(x) p(x) dx. \qquad (13)$$

Then, to consider characteristic functions, equation (13) comes out to be the following ergodic equality [27]:

$$\lim_{N \to \infty} \frac{1}{N} \sum_{n=1}^{N} \exp(ikx_i) = \int_{-\infty}^{\infty} \exp(ikx) f(x) dx, \qquad (14)$$

for which we have

$$\hat{\lambda}(k) = \lim_{N \to \infty} \frac{1}{N} \sum_{n=1}^{N} \exp(ikx_i). \qquad (15)$$

This assumption allows us to empirically obtain the probability distribution. Hence, the empirical characteristic function $\lambda_N(k)$ of a large number of data set $x_n (n = 1, 2, \ldots, N)$ can be calculated as

$$\hat{\lambda}_N(k) = \frac{1}{N} \sum_{n=1}^{N} \exp(ikX_n). \qquad (16)$$

When the data follow Levy's stable distribution with the parameters $(\alpha, \beta, \gamma, \delta)$ $(\alpha \neq 1, k > 0)$, the characteristic function can be presented as

$$\hat{\lambda}_N(k) = \exp\left[i\delta k - (\gamma k)^{\alpha}\left\{1 + i\beta \tan\left(\frac{\pi\alpha}{2}\right)\right\}\right] \qquad (17)$$

from equation (5). With equation (17), we can derive

$$\log(-\log|\hat{\lambda}_N(k)|) = \hat{\alpha}\log k + \hat{\alpha}\log\hat{\gamma} \qquad (18)$$

and

$$\frac{1}{k}arctg\left\{\frac{\hat{\lambda}_{N,\mathrm{I}}(k)}{\hat{\lambda}_{N,\mathrm{R}}(k)}\right\} = -\hat{\beta}\hat{\gamma}^{\hat{\alpha}}tg\left(\frac{\pi\hat{\alpha}}{2}\right)k^{\hat{\alpha}-1} + \hat{\delta}, \quad (19)$$

where each of $\hat{\lambda}_{N,\mathrm{I}}(k)$ and $\hat{\lambda}_{N,\mathrm{R}}(k)$ corresponds to the imaginary and real part of the empirical CF. Through linear regression method in equations (18) and (19) around $k = 0$ the parameters $(\alpha,\beta,\gamma,\delta)$ can be estimated. In case when $(\gamma,\delta)$ are far from the standard value of $(1,0)$, each parameter can not be estimated accurately. In this case the data should be normalized to $(\gamma,\delta) = (1,0)$ and then $(\alpha,\beta)$ can be estimated.

While the standard estimation method use the probability density function from the actual data with difficulty in estimating the tails of the distribution which are essentially important part of Levy's stable distribution, the method which we use in this paper can indicate the tail through the characteristic function. In addition, this method has a faster convergence according to the increasing number of data. The introduced integer $\tau_n(u)$ accounts for possible nonprincipal branches of the arctan function.

## 5. Data classification and calculated results

Recently, there has been an increasing of interest in the study of quantitative methods for the stability of financial objects, especially in crisis situations. It is extremely important to take precisely preventive measures to prevent significant financial losses. In this respect, an important role is played by the methods of constructing indicators of crisis phenomena, which warn in advance of a possible approaching crisis, that makes them as indicators-precursors of possible crisis states.

For the first time, the use of dynamic indicators, precursors of crashes in stock markets using the parameters of a $\alpha$-stable distribution, was proposed by us in the works [30, 31] and later repeated in a recent work [32]. Moreover, the authors [32], analyzing only one crisis of 2008 and using a limited set of stock market indices (only three), conclude that the $\beta$ parameter is an even more convincing indicator of the approaching crisis.

In this part we have estimated Levy's parameters for DJIA for the period from 1 March 2000 to 28 March 2019, the gold price for the period from 1 April

1968 to 8 May 2019 and Brent crude oil price for the period from 2 January 1986 to 6 May 2019. This data include stock indices of developed countries, developing and emergent markets. Their data were downloaded from Yahoo Finance (http://finance.yahoo.com), Investing.com (https://www.investing.com), FRED (https://fred.stlouisfed.org). The distribution parameters were found for the entire time series and the algorithm of a moving window. For moving window, the part of the time series (window), for which there were calculated corresponding parameters, was selected. Then, the window was displaced along the time series in definite increment (step) and the procedure repeated until all the studied series had exhausted. For our case the window width is 1000 days and time step is 5 days.

The considered assets for the specified period include crisis phenomena and these periods obviously affect the dynamics of distribution parameters. Therefore, you should calculate them in the model of the moving window and compare their dynamics with the dynamics of the original time series.

For analysing and explaining basic characteristics of complex systems with $\alpha$ - stable distribution, we have chosen Dow Jones Industrial Average index (DJIA) and gold with crude oil as the most quoted financial barometers in the world. In addition, like complex systems, financial markets with gold markets fascinating examples of complexity: a real world complex system whose evolution is dictated by the decisions of many people, generating huge amounts of data. For understanding of the falls that occurred on them, we analysed different scientific articles [31-33], and relying on our research, we classified them on crashes and critical event, and separated DJIA time series into two parts where first part occupies period from 2 January 1920 to 3 January 1983 and second part from 4 January 1983 to 18 March 2019, for having better overview of its dynamics. Note that the data set here is an every 1-day data, except those when stock market closed and does not work. During our research it was established that:

1. Crashes are short, time-localized drops, with strong losing of price each day.

2. Critical events are those falls that, during their existence, have not had such serious changes in price as crashes.

Table 1 shows the major crashes and critical events of DJIA index related to our classification.

**Table 1.** Major Historical Corrections of DJIA index since 1920

| N | Interval | Days in correction | Decline, % |
|---|---|---|---|
| 1 | 03.09.1929-29.10.1929 | 41 | 39,64 |
| 2 | 01.03.1938-31.03.1938 | 23 | 24,15 |
| 3 | 08.04.1940-05.06.1940 | 42 | 25,10 |
| 4 | 21.08.1946-10.09.1946 | 14 | 16,35 |
| 5 | 30.07.1957-22.10.1957 | 60 | 17,51 |
| 6 | 19.03.1962-28.05.1962 | 50 | 19,91 |
| 7 | 18.07.1966-07.10.1966 | 59 | 12,84 |
| 8 | 09.04.1970-26.05.1970 | 34 | 20,35 |
| 9 | 24.10.1974-04.10.1974 | 52 | 27,45 |
| 10 | 02.10.1987-19.10.1987 | 12 | 34,16 |
| 11 | 17.07.1990-23.08.1990 | 28 | 17,21 |
| 12 | 01.10.1997-21.10.1997 | 15 | 12,43 |
| 13 | 17.08.1998-31.08.1998 | 11 | 18,44 |
| 14 | 14.08.2002-01.10.2002 | 34 | 19,52 |
| 15 | 16.10.2008-15.12.2008 | 42 | 30,21 |
| 16 | 09.08.2011-22.09.2011 | 32 | 11,94 |
| 17 | 18.08.2015-25.08.2015 | 6 | 10,53 |
| 18 | 29.12.2015-20.01.2016 | 16 | 11,02 |
| 19 | 03.12.2018-24.12.2018 | 15 | 15,62 |

As it is seen from the Table 1, during DJIA index existence, many crashes and critical events shook it. According to our classification, events with number (1, 10, 13, 15) are crashes, all the rest – critical events. Tables 2 and 3 demonstrate classification for the falls that have occurred in the gold and oil markets.

**Table 2.** Major Historical Corrections of Brent crude oil since 1986

| N | Interval | Days in correction | Decline, % |
|---|---|---|---|
| 1 | 11.10.1990-07.02.1991 | 84 | 48,06 |
| 2 | 29.09.1998-25.11.1998 | 42 | 32,16 |
| 3 | 14.09.2001-15.11.2001 | 45 | 40,85 |
| 4 | 09.08.2006-22.09.2006 | 32 | 21,61 |
| 5 | 14.07.2008-23.12.2008 | 115 | 79,14 |
| 6 | 07.11.2014-28.01.2015 | 55 | 44,00 |
| 7 | 10.06.2015-26.08.2015 | 55 | 37,26 |
| 8 | 01.10.2018-18.12.2018 | 55 | 38,80 |

**Table 3.** Major Historical Corrections of the gold price since 1968

| N | Interval | Days in correction | Decline, % |
|---|---|---|---|
| 1 | 22.04.1974-04.07.1974 | 54 | 26,18 |
| 2 | 21.01.1980-18.03.1980 | 42 | 43,50 |
| 3 | 06.09.1982-04.10.1982 | 21 | 18,24 |
| 4 | 08.10.1986-24.11.1986 | 34 | 13,14 |
| 5 | 12.05.2006-14.06.2006 | 24 | 21,69 |
| 6 | 06.09.2011-15.12.2011 | 73 | 16,93 |
| 7 | 27.03.2013-28.06.2013 | 68 | 25,64 |

Accordingly, we emphasize that for oil events with numbers (1, 2, 3, 5, 6, 7, 8) are critical events, event with number 4 is crash. The gold market has critical events with numbers (1, 2, 4, 6, 7), crashes are defined as (3, 5).

From the data above, we estimate the parameters $\alpha$ and $\beta$ of the stable distribution that the best describes the empirical returns.

Further, comparing the dynamics of the actual time series and the corresponding measures of complexity, we can judge the characteristic changes in the dynamics of the behavior of complexity with changes in our time series. If the estimated parameter behaves in a definite way for all periods of crashes, for example, decreases or increases during the pre-critical period, then it can serve as an indicator-precursor of such a crashes phenomenon.
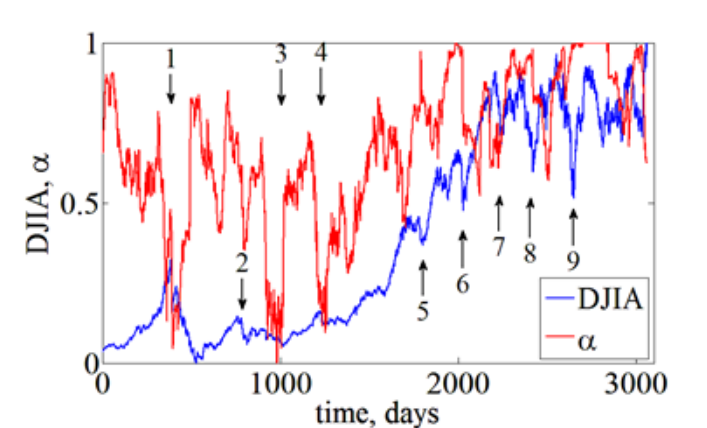


a)
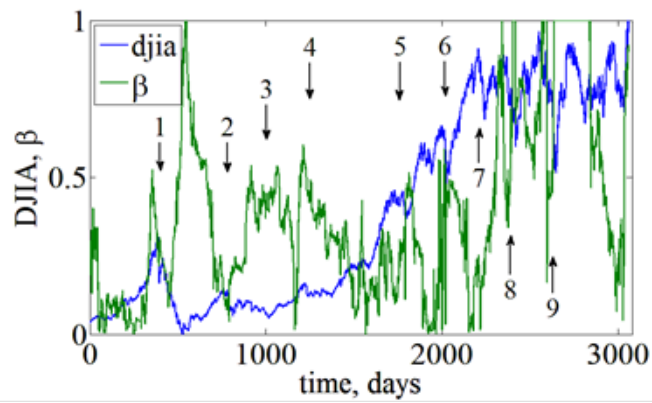
b)
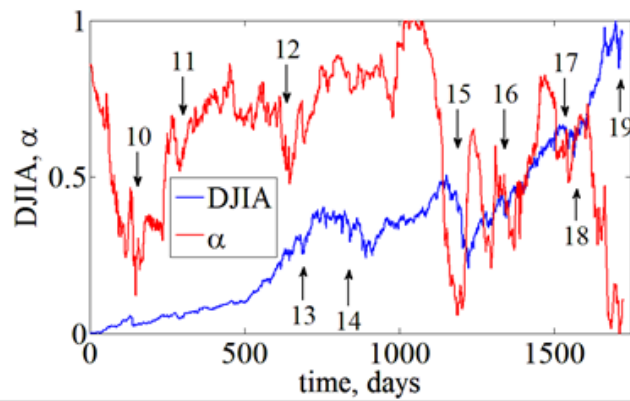


c)



d)

**Fig. 1.** The DJIA time series and estimated for them parameters $\alpha$ (a, c) and $\beta$ (b, d). Vertical arrows indicate crashes and critical events.

a)



b)

**Fig. 2.** The corresponding time series of Brent crude oil (a), gold price (b) and estimated for them parameters $\alpha$ and $\beta$. Vertical arrows indicate crashes and critical events.

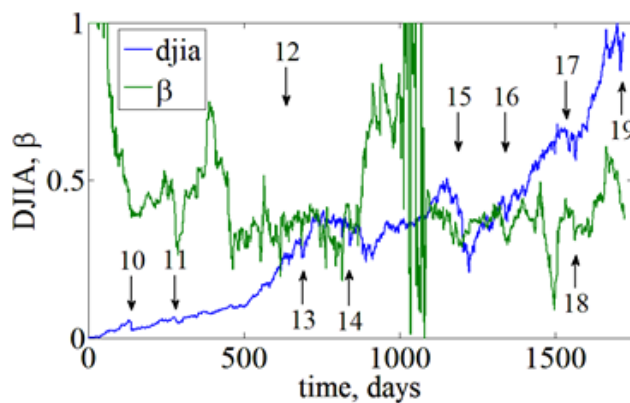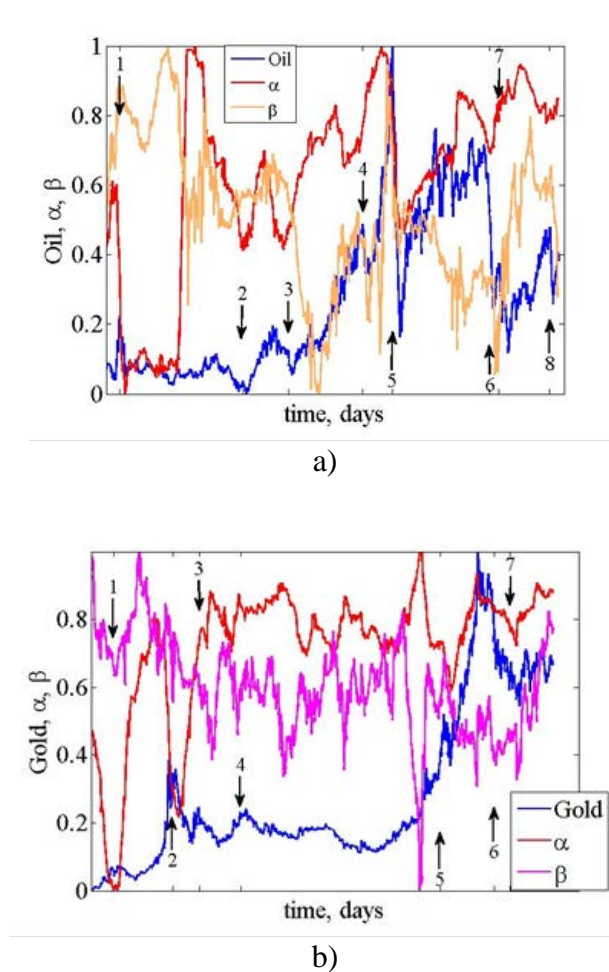From the figures above we can see that our parameters start to decrease in crisis states. Such abnormal behavior can serve as indicator or precursor of crashes and critical states.

## 6. Conclusions

Thus, on the example of the US stock market (according to DJIA) and the spot markets (gold and oil) we have shown that the normalized log-returns of the considered assets do not correspond to the Gaussian distribution, have heavy tails and can be described more suitably by the Levy's stable distribution. The parameters $\alpha$ and $\beta$ are not constants and may vary depending on the dynamics of the relevant market. Therefore, we have estimated them using procedure of the moving window. We consider that they are universal, regardless of the nature of the financial asset, but such conclusions require additional research and arguments.

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### 1.17. Методичні аспекти оцінки ризиків системи газопостачання з урахуванням розвитку людських ресурсів

**Постановка проблеми.** Функціонування системи газопостачання в сучасних умовах супроводжується ризиками, які несуть в собі можливості настання несприятливих подій та їх економічних наслідків. Надійність системи суттєво залежить від якості устаткування, рівня її експлуатації та безперебійності постачання споживачам якісного газу. У зв'язку з цим на сьогодні, з одного боку, актуальними є питання оцінювання чинників впливу на надійність роботи системи газопостачання, її підсистем та об'єктів та визначення рівня ризику для прийняття рішень щодо підвищення ефективності роботи газотранспортних підприємств, а з іншого – чинників впливу на розвиток персоналу цих підприємств. Саме від умінь, знань, навичок останніх залежить ефективна робота газотранспортної системи України.

**Аналіз останніх досліджень і публікацій, в яких започатковано розв'язання даної проблеми.** Теоретико-методологічним та практичним аспектам щодо методів оцінки ризиків присвячено багато праць зарубіжних та вітчизняних науковців, серед них, Балдіна К., Брігхем Е., Васюренко О., Вітлінський В., Голуб Г., Донець Л.,Ілляшенко С., Корнійчук М., Лук'янова В., Марковіц Г., Машина Н., Месен Д.,Тобін Дж., Фрідмен Д., Хейне П., Христіановський В., Черкасов В., Шарп В., Штефанич А. та інші. Проблемі розвитку та ефективності використання кадрового потенціалу багато уваги приділяється в наукових працях Г. Десслера, Е. Мейо, М. Мескона, М. Долішнього, А Колота, В. Онікієнка, Ф. Хміля, Г. Щокіна та ін.

**Виділення невирішених частин загальної проблеми.** Ефективному розвитку та стабільності функціонування газотранспортних підприємств можуть загрожувати ряд небезпек, які необхідно вчасно ідентифіковувати, оцінювати та приймати відповідні управлінські рішення, що забезпечать безперебійну та рентабельну роботу цих суб'єктів господарювання. На

**Maksishko N., Cheverda S., Vasilieva O., Basov D. Comparative analysis of quality of forecast models of dynamics of financial instruments with consideration of the mine depth.**

Two types of models are constructed: first, models of exponential smoothing, related to classical statistical models, and, secondly, an alternative class of models of a homogeneous structure. These models are applied to two time series: gold prices and currency pair EUR / USD for the period from April 2018 to March 2019.

**Merkulova T., Yantshevich A. Tax regulation of income distribution: mathematical analysis of some problems.**

The problems with the non-taxable minimum income and the choice of taxation scale are considered. The obtained results allow carrying out multivariate calculations in order to analyze the influence of the parameters of the initial distribution of the tax progression on the distribution of net income and its inequality, as well as to set the task of finding the parameters of the tax scale.

**Oleinik V., Yatsenko V. Optimal management of investment flows of the enterprise.**

This article discusses the formulation and solution of some problems of managing the company's investment flows. One-product dynamic macroeconomic model is considered. When solving the problems posed, the Pontryagin maximization method is used. As a condition of optimization the criterion of maximization of the enterprise income is used. The optimal distribution of the gross product is given.

**Porokhnya V., Ivanov R. Modeling activities of households in the general economic structure of the state.**

The conceptual approach, based on the use of neural network modeling, with which one can consider development strategies of households from the point of view of planning the components of their economic behavior, is proposed. It is confirmed that the main factor of adaptation of a household in the conditions of economic instability is the increase of income in the form of profit and mixed income. The effectiveness of such a strategy should be ensured by the relevant economic policy of the state.

**Ramazanov S., Stepanenko O., Chernyak O., Tishkov B. Models and technologies of forecasting and problem future design: status analysis and separate results.**

The problem of sustainable development has a variety of aspects: systemic, synergistic, ecological, economic, mathematical, informational, philosophical,

legal, educational, etc. The paradigm of sustainable development requires the transition from the study of separately functioning isolated systems to the study of integral evolving systems, the actualization and promotion of system-synergies of the open system and its environment. On the basis of application of informational and innovative technologies for prediction of nonlinear dynamics of ecological-economic and social-humanitarian systems, integrated stochastic models of objects and processes suitable for conditions of systemic crises are developed and investigated. The concept of integration of 4 spheres of activity and functioning of modern complex systems is considered. A general conceptual-integrated integrated model is proposed, a synergetic model of dynamics based on uncertainty (stochastic and chaotic components) is generalized. To predict the development of an innovative economy, an integrated stochastic nonlinear model of growth dynamics in the phase space was previously developed and investigated. We are convinced that environmental problems (including crises and cats trophies) not only reflect the contradictions between society and nature - they have always been the projection of internal dissonances in the spiritual culture, or rather, the inconsistencies in the development of the human mind. And that at this stage of evolution, as before, the quality of the mind, more than any other parameter of the system, determines the objective limits of growth.

**Bielinskyi A., Semerikov S., Solovieva V., Soloviev V. Levy Distribution Parameters as Precursors of Crisis Phenomena.**

In spite of popularity of the Gaussian distribution in financial modeling, we demonstrated that Levy's stable distribution is more suitable due to its theoretical reasons and analysis results. We study the possibility of construction indicators-precursors relying on one of the most power-law tailed distributions - Levy's stable distribution. Here, we apply moving window based procedure for calculation of Levy's parameters - $\alpha$ - stability and $\beta$ - skewness for daily values of Dow Jones Industrial Average (from 1 March 2000 to 28 March 2019), the gold price (from 1 April 1968 to 8 May 2019) and Brent crude oil price (from 2 January 1986 to 6 May 2019) which show their effectiveness as indicators of crisis states. For the construction of the indicators, were selected time series of and, accordingly, for oil. Dow Jones' time series has the period from 2 January 1920 to 2019. We conclude that $\alpha$ and $\beta$ parameters of Levy's stable distribution of the observed assets, which demonstrate characteristic behavior for crash and critical states, can serve as an indicator-precursors of the unstable states.

# АКТУАЛЬНІ ПРОБЛЕМИ ПРОГНОЗУВАННЯ РОЗВИТКУ СОЦІАЛЬНО-ЕКОНОМІЧНИХ СИСТЕМ

*Монографія*

*За редакцією: О.І. Черняка, П.В. Захарченка*