“Methods for prediction of economic crises in the global economy and financial centers”

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Methods for prediction of economic crises in the global economy and financial centers

Abstract

The paper studies the issues pertaining to the timely identification of economic crises under conditions of globalization. It offers an integral indicator of the economy's development level (global economy and financial centers), carries out the filtering of the trend and systemic components of this indicator's time series, which makes it possible to determine the cyclicity of crises and to predict the min short-term and long-term perspective. It introduces the indicator to formalize and quantify the crises on the global scale and in the three major financial centers (the United States, Europe and Asia). It also examines the adequacy of the proposed approach based on the dynamics of the global crises over the past 50 years.

Keywords: crisis indicator, integral indicator, level of economic development, forecasting, decomposition analysis, regression analysis.
JEL Classification: G10

Introduction

With the transformation of the global financial architecture the strengthening of integration processes within the national and international financial markets is occurring. Along with the free movement of the capital, goods and services the crisis phenomena and their destructive impact on the economy are increasing. Therefore, the need for preliminary identification, monitoring and development of measures to mitigate the negative effects of the market, interest rate, currency, political and other risks determines the necessity of forming the instruments of economic and mathematical modeling and forecasting of crises.

1. The main results of the research

In the recent decades the economic development has been accompanied by the search for instruments of an early warning and detection of imbalances in the national economies. Integration processes, which have covered the whole range of social activities, led to the rapid expansion of destructive factors both within and outside individual countries. Crisis phenomena on certain markets destabilize the effective functioning of the whole financial system of a country. The high level of interconnection and interpenetration of domestic and international financial markets leads to the negative synergistic effect and the loss of equilibrium by the entire global economy.

The identification of sources of financial instability at the level of individual countries and financial centers is the basis for the prevention of possible shocks to the global economy. The forecasting of crisis at the local level makes it possible to reduce financial losses and, considering the characteristic features and economic potential of the regions, improve the effectiveness of preventive measures. The forecasting of the cyclicity of the world economy also serves as an essential element of effective crisis assessment and prevention systems. This is connected to the ability to form a coherent strategy for an early detection of crises and to create conditions for overcoming their consequences.

Therefore, the formation of scientific and methodical approach for the formalization of the process of prediction of global economic crises under conditions of integration is becoming increasingly relevant.

Based on the importance of this problem we propose a methodology for the forecasting of crises in the global economy. We will consider the stages of this methodology.

Stage 1. *Formation of the knowledge base of research* – relevant indicators of the level of development of the world economy and its three financial centers (the United States, Europe and Asia [2]). Selection of data about the financial centers and a further study of peculiarities of crisis forecasting within national economies caused by the different mentality of the population and the structure of financial systems. As a knowledge base of the proposed approach we consider the data describing the development of the world economy during the period 1960-2012 and serving directly or indirectly as indicators of crises. The source of the input information base for our research is the website of the World Bank [9]. Similar tables have been drawn up for the financial centers.

Stage 2. *Bringing the indicators of Table 1 to comparable form.* As input indicators have different effects on the resultant indicator and have different measurement units, it is proposed to normalize the input data base through the use of the following mathematical correlations:

for destimulating indicators – savage normalization:

$$NC_{it} = \frac{C_{it} - \min\limits_{t}\{C_{it}\}}{\max\limits_{t}\{C_{it}\} - \min\limits_{t}\{C_{it}\}}, \quad (1)$$

where C_{it} is a relevant indicator of the global economy's (financial centers') development level characteristics during the *t*-year; NC_{it} – normalized value of the indicator during the *t*-year;

for stimulating indicators – natural normalization:

$$NC_{it} = \frac{\max\limits_{t}\{C_{it}\} - C_{it}}{\max\limits_{t}\{C_{it}\} - \min\limits_{t}\{C_{it}\}}. \quad (2)$$

The results of realization of this stage for the world economy are presented in Table 2 (See Appendix).

Stage 3. *Calculation of the integral indicator for the development level of the global economy and world financial centers*, which is based on the convolution of the normalized indicators presented in Table 2. It is assumed that the weight of the input information base indicators will be the same. Thus, at this stage the calculations will be conducted by using the following formula:

$$IIC(t) = \sum_{i=1}^{n} NC_{it}, \quad (3)$$

where $IIC(t)$ is an integral indicator of the level of economic development (world economy or a certain financial center) in the period *t*.

Practical results of implementation of the abovementioned approach, namely, the calculated values of the integral indicator of the economy's development level for each year in the period of 1960-2012 are presented in graphical form (Figure 1 in Appendix).

On the basis of the graphical analysis we made the following conclusions:

- There is a growing oscillating trend in the *IIC* indicator. This shows the progressive development of the economy and realization of the existing potential despite certain periods of financial instability.
- One can observe a cyclical change of the *IIC* indicator making it possible to identify the periods of economic booms and recessions.
- There are periodic changes in the leading position among the American and the European financial centers; countries, which form the Asian financial center, demonstrate the record growth of economic development.

Stage 4. *Research and periodization* of global crises from 1960 to 2012 as a basis for examining the adequacy of economic and mathematical model (Table 3 in Appendix). Based on systematization of the existing approaches to defining crises, their factors, negative consequences and duration [2, 3, 5, 9, 10, 12] in the period 1960-2012, we will consider the international financial crises, the characteristics of which are presented in Table 3.

Thus, over the past 50 years there have been 4 global economic crises, the biggest of which was the crisis of 2008-2010.

Stage 5. *Selection and justification of the crisis indicator* as an indicator, which makes it possible to predict with the highest degree of accuracy the occurrence of a crisis and to make appropriate managerial decisions to counteract it [12]. As the *IIC* indicator shows the average trend, it is proposed to analyze its derivatives in order to interpret the crises [6].

We consider different approaches to determining the crisis indicator. On the basis of identification of their main advantages and drawbacks we will formulate the basic requirements for the application of these methods. For example, as a crisis indicator we consider the value of the chain growth rate time series for the integral indicator of the economic development (Figure 2 in Appendix).

The analysis of data (Figure 2) reveals all crisis periods (shown in Table 3) in which the smallest values of this indicator are observed. The only exception is the economic bubble of 2001-2003, in which the crisis indicator does not adopt the smallest values, but there is a much longer period of oscillation of this indicator at a zero level compared to othertime intervals.

The crisis indicator may be the testing of the anomalous levels of the global economy's integral indicator [8] according to the Irwin method (Figure 3).

$$\lambda(t) = \frac{\left| IIC_t^W - IIC_{t-1}^W \right|}{\sigma_{IIC^W}}, \quad (4)$$

where $\lambda(t)$ is the characteristics of the anomalousvalues of the *ICC* indicator in time *t* - the crisis indicator when estimated values exceed critical table values χ^2; σ_{IIC^W} is a standard deviation for the values of the *IIC* indicator.

On the basis of the graphical analysis we discover that the anomalous levels of the *ICC* indicator are the values of the crisis periods, which are characterized by a significant deviation from its average value. Considering the fact hat the database (Figure 3) can help reveal all crisis periods from 1960 to 2012, it would be right to regard it as a crisis indicator.

Thus, one could argue that the most informative indicator in terms of identifying crisis phenomena seems to be the anomalous levels of time series.

Stage 6. *Identification of crisis phenomena on the basis of the indicator of anomalous levels of time series for the IIC indicator and the testing of the developed model's adequacy.* The realization of this stage involves the definition and graphical representation of crisis indicators (Figure 4 in Appendix).

Based on the comparison of the data (Figure 4) and major financial shocks (Table 3), it can be argued that the obtained results with their marginal deviations and with the time lag between the initial impact of the factor and its subsequent effects correspond to the actual statistical data, confirming the expediency of using the developed crisis indicator in crisis forecasting.

Stage 7. *Decomposition of time series for the values of the IIC indicator* [1, 11]. The realization of this stage gives an opportunity to determine the trend in the changes of the indicator, the cyclicity of crises and to get a mathematical provision in the form of regression equations for predicting the anomalous levels and making decisions regarding the preventive measures. Thus, it is proposed to detect the presence of systematic components of the tested time series based on the correlogram for first differences (Figure 5 in Appendix).

The dependence of autocorrelation coefficients on the value of the time lag shows the following:

- Autocorrelation coefficient for the time lag of one year is statistically significant, which (though not showing the cyclicity of crises) confirms the lag of information flow.
- Autocorrelation coefficient for the time lag of 4 years is statistically significant, i.e. the cyclicity of crises and anomalous values of the crisis indicator are characterized by the time interval of 4 years.

In its turn, the correlogram of zero differences for the *IIC* indicator's successive values demonstrates the specification of unsystematic component (trend) of this time series in the form of second-degree polynomial. Statistical estimations of the parameters of nonlinear regression for the trend component, the corresponding standard errors, the confirmation of the statistical significance of coefficients and their intervals are presented in Table 5 (See Appendix).

Thus, on the basis of the data in the column "Coefficients" of Table 5 and the results of filtration of the cyclical component of time series for the values of the *IIC* indicator with the help of seasonality index, it is proposed to build the following trend-cyclical additive model:

$$IIC^{W}(t) = 0.0016 \cdot t^2 + 0.0294 \cdot t + 4.8026 - \\ - 0.0166 \cdot I_1 - 0.0274 \cdot I_2 - 0.0988 \cdot I_3 + 0.1092 \cdot I_4, \quad (5)$$

where $IIC^{W}(t)$ is an integral indicator of the level of the global economic development in the period t; I_1 (I_2, I_3, I_4) is an indicator of each of the first (second, third, fourth) year since 1960 at intervals of 4 years, which adopts a unit value in the described case and a zero value in the opposite case.

The characteristic of the cyclic component (equation (5)) makes it possible to conclude that fluctuations happen every fourth year since 1960. The first three years are characterized by a significant downward trend while the last fourth year is characterized by a slight growth as the coefficient of the dummy variable I_4 takes on positive values showing the growth of the world economy's integral indicator by 10.92%. At the same time, it should be noted that this paper describes only the behavior of cycles. In the future, it is necessary to carry out adjustments regarding the dynamic component, which will indicate the presence of crisis phenomena.

Stage 8. *The building of autoregressive linear equations for the dependence of the integral indicator of financial centers' development level on the values of the same time series shifted by several years* [4, 7]. At this stage calculations form the equation systems (autoregressive line armultifactor equation for the dependence of the integral indicator of financial centers' development level on the values of the time series with lags from 1 to 5 years; equation of dependence of the examined result characteristics with a 5 year lag, which allows to make predictions for 5 years into the future; multifactorial line arregression equation for the dependence of the integral indicator of financial centers' development level on the relevant characteristics of the objects of study in terms of describing the crisis phenomena) and are conducted both in the context of the global economy:

$$\begin{cases} IIC^{W}(t) = 0.1590 + 0.6601 \cdot IIC(t-1) + 0.2391 \cdot IIC(t-2) - \\ - 0.0589 \cdot IIC(t-3) - 0.1925 \cdot IIC(t-4) + 0.3630 \cdot IIC(t-5) \\ IIC^{W}(t) = 0.6218 + 0.9948 \cdot IIC(t-5) \\ IIC^{W}(t) = 52.9059 - 1.8217 \cdot C_1(t) - 0.1342 \cdot C_2(t) - 0.1564 \cdot C_1(t) - \\ - 0.1341 \cdot C_4(t) + 0.0424 \cdot C_5(t) - 0.5752 \cdot C_6(t) - 0.1637 \cdot C_7(t) - \\ - 0.0453 \cdot C_8(t) - 0.0619 \cdot C_9(t) - 0.0077 \cdot C_{10}(t) - 0.0237 \cdot C_{11}(t) + \\ + 0.3679 \cdot C_{12}(t) + 0.7847 \cdot C_{13}(t) + 0.0091 \cdot C_{14}(t) - 0.0178 \cdot C_{15}(t) \end{cases}$$

and within individual financialcenters:

American:

$$\begin{cases} IIC^{AM}(t) = 0.0021 \cdot t^2 - 0.0752 \cdot t + 6.9187 + \\ + 0.0413 \cdot I_1 + 0.0172 \cdot I_2 + 0.0015 \cdot I_3 - 0.0391 \cdot I_4 \\ IIC^{AM}(t) = -0.3239 + 0.7716 \cdot IIC(t-1) + 0.4142 \cdot IIC(t-2) - \\ - 0.3781 \cdot IIC(t-3) + 0.0045 \cdot IIC(t-4) + 0.2460 \cdot IIC(t-5) \\ IIC^{AM}(t) = 0.0535 + 1.0011 \cdot IIC(t-5) \end{cases} \quad (6)$$

European:

$$\begin{cases} IIC^{EU}(t) = 0.0009 \cdot t^2 - 0.0068 \cdot t + 6.3807 - \\ - 0.0177 \cdot I_1 - 0.0012 \cdot I_2 + 0.0173 \cdot I_3 - 0.0803 \cdot I_4 \\ IIC^{EU}(t) = 0.4284 + 0.8421 \cdot IIC(t-1) - 0.0573 \cdot IIC(t-2) + \\ + 0.0299 \cdot IIC(t-3) - 0.0711 \cdot IIC(t-4) + 0.2014 \cdot IIC(t-5) \\ IIC^{EU}(t) = 2.7920 + 0.6128 \cdot IIC(t-5) \end{cases} \quad (7)$$

Asian:

$$\begin{cases} IIC^{AS}(t) = -0.0009 \cdot t^2 + 0.1207 \cdot t + 4.8572 + \\ + 0.0575 \cdot I_1 - 0.0106 \cdot I_2 - 0.0100 \cdot I_3 + 0.1303 \cdot I_4 \\ IIC^{AS}(t) = 1.0126 + 0.3380 \cdot IIC(t-1) + 0.3786 \cdot IIC(t-2) - \\ - 0.2741 \cdot IIC(t-3) + 0.1602 \cdot IIC(t-4) + 0.2865 \cdot IIC(t-5) \\ IIC^{AS}(t) = 2.0259 + 0.7711 \cdot IIC(t-5) \end{cases} \quad (8)$$

Stage 9. *Prediction of values of integrated indicators for the global economy's and financial centers' development level* in the period from 2013 to 2020 and determination of anomalous values for thesetime series as indicators of crisis phenomena in accordance with the Irwin method [13]. It is proposed to systematize the results of the calculations and present them in a tabular formin the context of the two research methods: decomposition analysis (Table 6) and autoregressive analysis (Table 7 in Appendix).

The analysis of the data in Table 6 reveals the following:

- two phases of the crisis the first, the end of 2014 and 2015, the second, in 2018 given the lag of 1 year between the anomalous level of the observed time series values and the cyclicity of depressions after 4 years;
- crisis phenomena expand, first of all, to the American center, for which the parameter of anomalous levels of time series for the crisis integral indicator does not have a lag as evidenced by statistically insignificant values of autocorrelation coefficients of the corresponding correlogram;
- after the American financial center the crisis with a one year lag extends to the European center where the first phase of the crisis will begin in 2015-2016, and the second phase with a lag of 4 years in 2019;
- although the Asian financial center is characterized by the late manifestation of crisis phenomena (2016-2017 and 2020, respectively), its

peculiar feature is the ability of an early prediction of possible negative consequences of the crisis – the availability of the time series anomalous values for the *IIC* indicator ahead of other financial centers.

The results of the integral indicator autoregressive analysis show with a slight deviation a similar trend regarding the periodization, duration and cyclicity of crises that have been identified through the method of decomposition analysis (Table 7).

Stage 10. *Development of a system of preventive-measures* to counteract the destructive factors of crises. The proposed instruments for crisis forecastingmake it possible to develop an effective set of measures against destructive influences. The availability of information about the periods of a crisis, its duration and expansion characteristics, creates an opportunity for supranational regulation of the process of counteraction to financial instability and, as a result, reduction of economic losses for individual states from crises.

Conclusions

The paper proposes: a crisis indicator on the basis of the Irwin test to examine the anomalous levels of time series; an integral indicator for the development level of the global economy and three major financial centers (American, European and Asian) on the basis of decomposition and autoregressive analysis making it possible to conduct an adequate prediction of crises under international integration. The proposed methods are the basis for effective decision-making regarding the development of measures to prevent crises and minimize their impact on the macro level.

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Appendix

Table 1. Information base for the research of the dynamics of the global economic development

Indicator	Indicator value by year						
	1960	1961	1962	…	2010	2011	2012
International migrant stock (% of population)*	2,6	2,6	2,6	…	3,1	3,1	3,2
Gross savings (% of GNI)**	20,1	20,1	20,2	…	22,9	23,5	23,6
GDP growth (annual %)*	4,3	4,3	5,6	…	4,0	2,8	2,2
Inflation, GDP deflator (annual %)*	2,5	2,5	2,6	…	4,5	5,7	3,2
Gross capital formation (annual % growth)**	2,6	2,7	2,7	…	9,6	4,9	4,9
Household final consumption expenditure, etc. (% of GDP)**	60,1	60,1	60,1	…	60,8	61,2	61,3
General government final consumption expenditure (% of GDP)**	13,5	13,9	14,1	…	18,6	18,3	18,4
Total tax rate (% of commercial profits)*	70,0	69,6	69,2	…	48,0	45,1	44,7
Compensation of employees (% of expense)**	23,6	23,6	23,6	…	22,7	21,5	21,5
Liquid liabilities (M3) as % of GDP*	37,3	38,0	34,5	…	46,9	48,9	50,7
Claims on other sectors of the domestic economy (% of GDP)*	201,6	200,4	199,2	…	150,2	145,1	147,3
Bank liquid reserves to bank assets ratio (%)**	6,1	6,2	6,4	…	14,6	14,6	15,2
Bank capital to assets ratio (%)**	6,0	6,0	6,1	…	9,5	9,7	9,7
Stocks traded, total value (% of GDP)**	15,8	16,3	16,8	…	105,1	97,0	72,7
Market capitalization of listed companies (% of GDP)**	41,4	41,9	42,4	…	87,5	67,8	77,2

Note: * Destimulating indicators (the growth of the indicator means stagnation (the decline means development)). ** Stimulating indicators (the growth of the indicator means development (the decline means stagnation)).

Table 2. Normalized values for the indicators of the world economy development level

Indicator	Indicator value by year						
	1960	1961	1962	…	2010	2011	2012
International migrant stock	0,56	0,59	0,61	…	0,04	0,02	0,00
Gross savings	0,00	0,02	0,03	…	0,72	0,90	0,91
GDP growth	0,26	0,27	0,12	…	0,29	0,43	0,51
Inflation, GDP deflator	0,99	0,99	0,98	…	0,85	0,77	0,94
Gross capital formation	0,65	0,66	0,66	…	0,98	0,76	0,76
Household final consumption expenditure, etc.	0,44	0,45	0,46	…	0,74	0,92	0,93
General government final consumption expenditure	0,00	0,06	0,10	…	0,95	0,89	0,91
Total tax rate	0,00	0,02	0,03	…	0,87	0,99	1,00
Compensation of employees	0,73	0,73	0,73	…	0,49	0,17	0,18
Liquid liabilities (M3)	0,95	0,93	0,99	…	0,79	0,76	0,73
Claims on other sectors of the domestic economy	0,00	0,02	0,04	…	0,91	1,00	0,96
Bank liquid reserves to bank assets ratio	0,00	0,01	0,02	…	0,93	0,93	1,00
Bank capital to assets ratio	0,00	0,01	0,03	…	0,94	0,98	1,00
Stocks traded, total value	0,00	0,00	0,01	…	0,54	0,49	0,34
Market capitalization of listed companies	0,00	0,01	0,01	…	0,60	0,34	0,46

Table 3. International crises (from 1960 to 2012)

Name of a crisis and global depression	Period	Duration	Causes
Oil crisis	1973-1975	2 years	4 times increase in oil prices, inflation.
Crisis of 1987 Recession of 1990	1987-1991	4 years	The dollar crisis, illiquidity of real estate.
Economic bubble	2001-2003	2 years	Events of September 11, 2001, accounting scandals.
International financial crisis of 2008-2010	2008 – beginning; 2009 – peak; 2010 – stabilization	1,5-3 years	Real estate, bankruptcy of banks.

Table 4. Periodization of international crises in the period from 1960 to 2012

Name of a crisis	Period	Anomalous values of the integral indicator for the financial centers' development level
Oil crisis	1973-1975	World economy 1974, 1976-1977 American center 1971-1973 European center 1974-1976 Asian center 1974-1976
Crisis of 1987 Recession of 1990	1987-1991	World economy 1986, 1995 American center 1984-1985, 1991 European center 1990-1991 Asian center 1990-1991, 1993

Table 4 (cont.). Periodization of international crises in the period from 1960 to 2012

Name of a crisis	Period	Anomalous values of the integral indicator for the financial centers' development level
Economic bubble	2001-2003	World economy 1999 American center 1999-2001 European center 1998-1999, 2001-2002 Asian center 1999
International financial crisis of 2008-2010	2008 – beginning; 2009 – peak; 2010 – stabilization	World economy 2007-2009 American center 2005, 2008-2012 European center 2007-2009 Asian center 2006-2011

Table 5. Results of the statistical analysis of the regression model data for the *IIC* indicator in the period of 1960-2012

	Coefficients	*Standard error*	*t-statistic*	*p-values*	*Lower 95%*	*Upper 95%*
Y-intercept	0,16	0,31	0,51	0,62	-0,47	0,79
Lag1	0,66	0,14	4,57	0,00	0,37	0,95
Lag2	0,24	0,18	1,36	0,18	-0,12	0,59
Lag3	-0,06	0,18	-0,33	0,74	-0,42	0,30
Lag4	-0,19	0,18	-1,07	0,29	-0,55	0,17
Lag5	0,36	0,15	2,39	0,02	0,06	0,67

Table 6. Prediction of crisis phenomena (anomalous levels) based on the results of decomposition analysis of the integral indicator as time series

Global level (world economy)		American center		European center		Asian center	
Year	Indicator of anomalous levels of the integral indicator of crisis	Year	Indicator of anomalous levels of the integral indicator of crisis	Year	Indicator of anomalous levels of the integral indicator of crisis	Year	Indicator of anomalous levels of the integral indicator of crisis
2013	0,319216	2013	0,257367	2013	0,028873	2013	0,974363
2014	0,064941	2014	0,532011	2014	0,998362	2014	0,208863
2015	0,15613	2015	0,311824	2015	0,717366	2015	0,197466
2016	0,111453	2016	0,33975	2016	0,74162	2016	0,287118
2017	0,329063	2017	0,294225	2017	0,016756	2017	0,946426
2018	0,074788	2018	0,568869	2018	1,043991	2018	0,236799
2019	-	2019	0,061305	2019	-	2019	0,021309
2020	-	2020	0,080989	2020	-	2020	0,003679

Table 7. Prediction of crisis phenomena (anomalous levels) based on the results of autoregressive analysis of the integral indicator as time series

Global level (world economy)		American center		European center		Asian center	
Year	Indicator of anomalous levels of the integral indicator of crisis	Year	Indicator of anomalous levels of the integral indicator of crisis	Year	Indicator of anomalous levels of the integral indicator of crisis	Year	Indicator of anomalous levels of the integral indicator of crisis
2013	0,658126	2013	0,41491	2013	2,087983	2013	0,838302
2014	0,521572	2014	0,21244	2014	0,397656	2014	1,287174
2015	0,063138	2015	1,137737	2015	0,298227	2015	0,529016
2016	0,162449	2016	0,852762	2016	0,028009	2016	0,498107
2017	0,160843	2017	0,941868	2017	0,651173	2017	0,30456
2018	-	2018	-	2018	-	2018	-
2019	-	2019	-	2019	-	2019	-
2020	-	2020	-	2020	-	2020	-

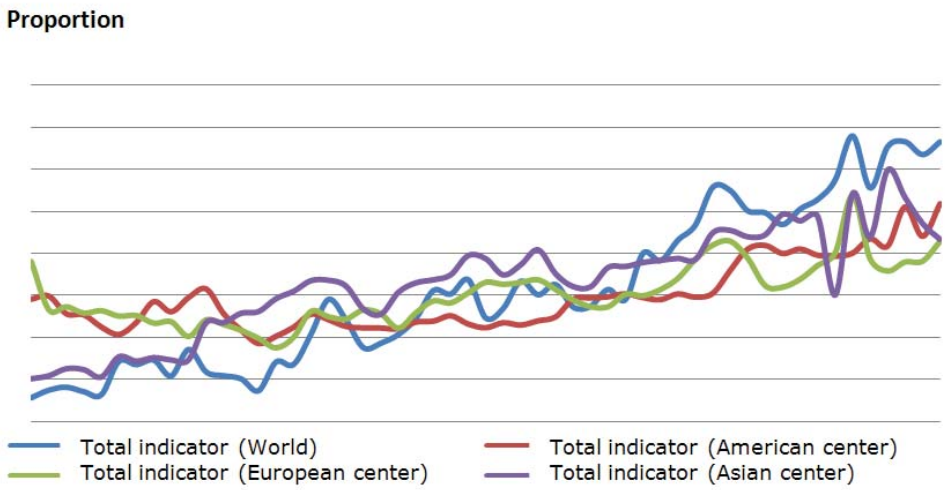

Fig. 1. Dynamics of the integral indicator for the development level of the global economy and three major financial centers

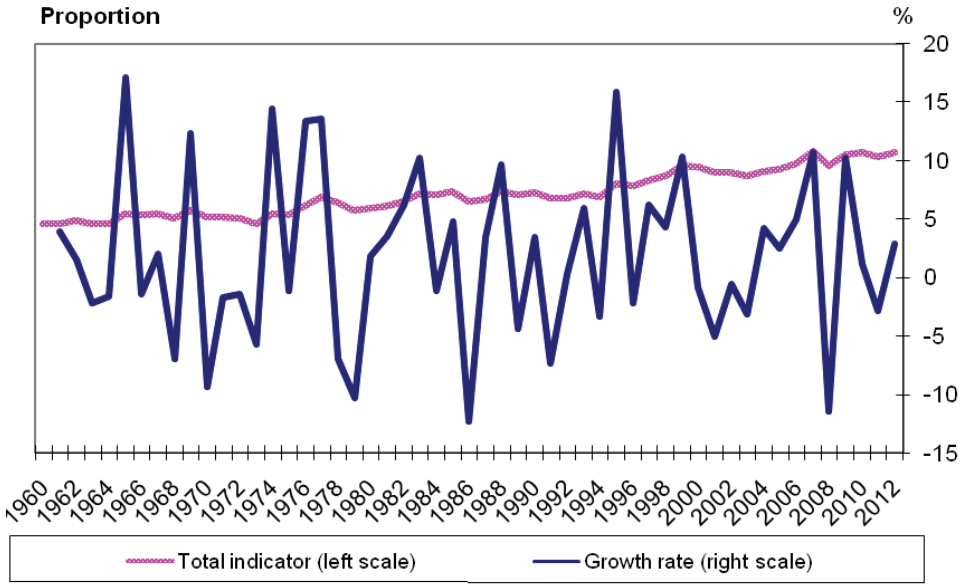

Fig. 2. Dynamics of the integral indicator of the global economy's development level and its growth rates over the period of 1960-2012

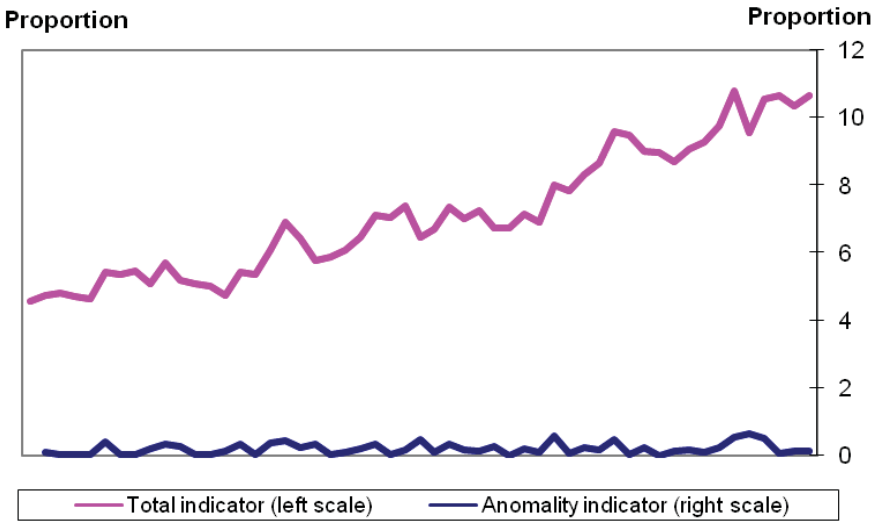

Fig. 3. Dynamics of the integral indicator of the global economic development and its anomalous levels over the period of 1960-2012

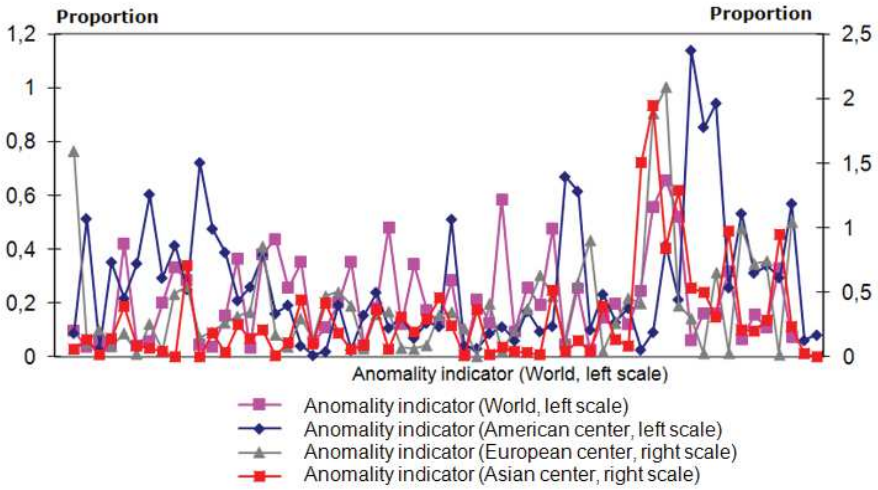

Fig. 4. Dynamics of anomalous levels of the *IIC* indicator

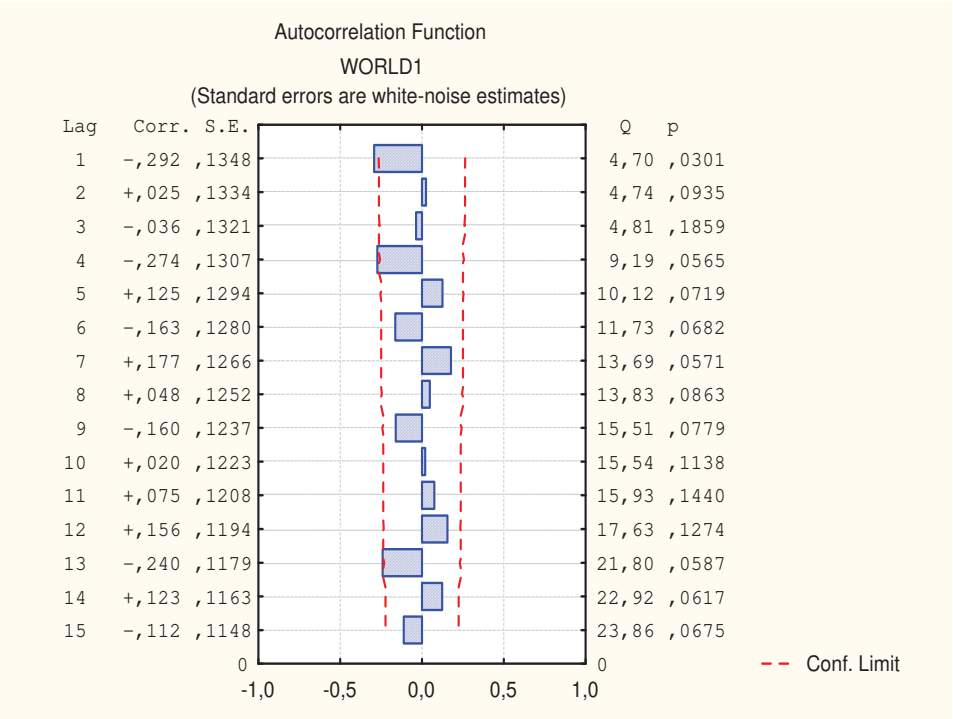

Fig. 5. Correlogram of dependence of autocorrelation coefficients on the value of the time lag of first differences for the *IIC* indicator