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PARADIGM TRANSFORMATION OF THE ECONOMIC CRISES MODELING

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ABSTRACT

In order to develop reasonable measures to counteract the destructive consequences of economic crises or to prevent them, it is important to build reasonable and adequate models of the emergence and course of crisis processes. The formal compliance of existing models with socio-economic processes during the crisis is often incomplete or cannot be adapted to other conditions, economies, and markets. Therefore, the article is devoted to the expediency and possibility of transformation of the existing paradigm of modeling economic crises.

Modeling the interdependence of two basic indicators, which characterize the crisis in the economic development of European countries (GDP growth rates and employment growth rates), refuted the possibility of their mutual determination. The interdependence of the dynamics of GDP growth rates and employment growth rates for all studied objects without a shift in time, determined for the period 1996-2020 with a high level of reliability, is of the same type and made it possible to determine the range of their mutual changes. According to this range and the parameters of the codependency's of GDP growth rates and employment growth rates, eight clusters of countries were determined by the method of finding concentrations. The emergence of crisis processes coincides with specific parameters of the interdependent dynamics of GDP growth rates and employment growth rates but is not related to the internal division of Eurozone countries into clusters.

The obtained results gave reason to put forward an alternative paradigm for modeling crisis processes, according to which economic crises arise as a result of the impact of random destructive events on systemic coincidences of potential periods of shifts in the contingent regularities of partial self-similar dynamics of economic processes. Within this paradigm, modeling of economic crises and forecasting their occurrence will be based on the study of self-similarity, dissipativeness and contingency of the dynamics of economic processes.

Keywords: economic crisis, determinism, stochasticity, modeling, contingency, dynamics, GDP growth rates, employment growth rates

JEL Classification: E17, O47, C01

INTRODUCTION

The emergence of crises has become an integral part of modern socio-economic realities. Crises can be global or local in nature, and cover entire spheres of social life, individual commodity, or financial markets. Predicting their occurrence is becoming more and more difficult, especially given the fact that the factors causing crises may not relate to those groups of social relations in which crisis phenomena manifest themselves clearly. Also, an increase in the frequency or severity of socio-economic and financial crises is a marker of the growing instability of the socio-economic base as a whole. Therefore, the task of predicting the onset of crises is closely related to the prediction of systemic breakdowns in the economy and society.

In connection with this, the question of the occurrence of crises due to systemic or random factors arises. In other words, it is necessary to find out what are the main factors of the emergence of crises - deterministic or non-deterministic. Confirmation of the naturally determined nature of modern socio-economic crises or, on the contrary,

its denial is an important and urgent task of modern economic science, the solution of which will make it possible to use more effective levers to overcome possible negative consequences.

LITERATURE REVIEW

In the study of the sources of emergence and regularities of the course of crises, the theoretical foundations of understanding their essence, varieties, and mechanism are of particular importance. It is the theoretical foundations of understanding crisis phenomena that are the subject of scientific works by O. B. Vatchenko and R. S. Sharanov (2019), Yu. P. Vladyka (2017), M. M. Korol (2020), A. V. Korotayev and S. V. Tsirel (2010), Yu. V. Myroshnychenko and E. V. Momot (2011), M. V. Savchenko and O. V. Shkurenko (2018), O. Shatailo (2019), V. Ye. Khrustova and P. V. Pronoza (2011) and others. At the same time, the specifics of the dynamics of crisis processes are noted in each individual case. Scientists often note the peculiarities of the course of individual crises, dividing them into cyclical and non-cyclical. In some works, it is claimed that economic crises are, as a rule, cyclical and regular, and financial crises are non-cyclical and specific (L. A. Sybyrka, 2012). Quite often, the combination of factors causing crises turns them into hybrid ones (D. V. Kislov, 2019). The mechanism of occurrence of certain crises is generally considered unique. The crises of the 19th century is mainly of a commodity nature, testifying to the overheating of the economy, and its oversaturation with the money supply. In the 20th century, financial factors became increasingly important in the emergence of crises. Among the factors that caused the development of crises in this period: the bankruptcy of the most significant financial institutions; risky speculative operations on stock markets; the collapse of the "gold standard"; outflow of investments associated with inflated expectations of investors; political factors; overheating of individual markets, etc. At the same time, the factors of economic crises can be completely unrelated to the economy, such as the crisis of 2020-2021, defined by the Covid-19 pandemic. A combination of economic and non-economic factors or economic factors of different genesis is possible and even frequent.

The sources of occurrence and consequences of the crisis of 2008-2010 were analyzed in the most detail, which is connected with its recent nature and detailed description according to many parameters. So, S. S. Patsykivskyi (2010), characterizing the dynamics of crisis processes in the Eurozone countries during the 2008-2010 crisis, notes its debt nature. In the report of A. Gurría (2009), the common cause of the crisis of 2008 was called the equalization of previously accumulated imbalances, the source of which is the growth of credit, stock prices, and real estate. A. Kriwoluzky (2020) defines the crisis of 2008-2010 as a crisis of demand when the collapse of financial institutions led to an increase in the price of money, which determined insufficient demand. S. Claessens and M. A. Kose (2013) among the types of crises based on various factors distinguish currency crises, market shutdown crises, debt crises, and banking crises.

Based on this, there are a significant number of approaches to modeling macroeconomic processes with the definition of prerequisites and the description of the course of crises in individual national economies or their groups. For example, there is a global macroeconomic model based on strict microeconomic dependences of the optimization of utility and profit in commodity, labor, and financial markets (QUEST), which is used by the Directorate-General for Economic and Financial Affairs (DG ECFIN) aimed at studying shocks, assessing the main drivers of growth and imbalances. Macroeconomic models for groups of countries estimate disaggregation at the regional and industry level. Other models are aimed at estimating the impact of mortgage obligations or debt obligations on the occurrence of shocks. For example, J. Baltazar, J. Reis, and M. Amorimc (2021) model the course of macroeconomic processes in the United Kingdom with the definition of periods of crises from the 1st quarter of 2019 to the 4th quarter of 2023 using methods: Monte Carlo - to determine the stress conditions; reverse transformation - to determine the default ratio; visualization of R Shiny - to determine the convergence of the crisis processes of 2008-2009 and macroeconomic processes in the United Kingdom in the period 2019-2023. W. J. McKibbin and A. Stoeckel (2009) model the crisis of 2008 using a dynamic stochastic equilibrium model, covering six manufacturing sectors in fifteen major economies. P. Pascal (2019) uses a standard macroeconomic model, supplementing it with factors such as financial intermediation, long-term loans, and random financial shocks. The model of P. Pfeiffer, J. Varga, and J. Veld (2021) reproduces the relationship between GDP growth, public spending, and public debt for EU countries. Moreover, when modeling, a number of assumptions are made, which simplifies the order and description of the dynamics of the characteristics of debt, expenses, and tax revenues. Lags are not determined between most of the parameters by which the model is built. In 2020, Bellia M., Cales L., Frattarolo L., Maerean A., Monteiro D., Giudici M. P., and Vogel L. presented a model describing the crisis of 2010-2012 as a consequence of the close connection of the state and banking sectors, which generates their direct and reverse negative influence on each other. Moreover, the level of risk and the degree of its influence on the further development of the crisis is determined by the verification of the banking sector. G. Kharlamova, A. Stavytskyy, O. Chernyak, V. Giedraitis, and O. Komendant (2019) model the 2008-2009 crisis as a gap in GDP production using univariate and multivariate Hodrick-Prescott filters.

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Thus, the majority of scientific works on modeling and forecasting of economic crises can be divided into two parts: those that focus primarily on their legally determined nature, associated with the cyclical development of the economy, and those that depend on the equal importance of relationships in real or/and financial sectors and specific impacts of various shocks. It should be noted that cyclicality in the dynamics of socio-economic phenomena and processes is the basis of the scientific paradigm. The existence of cycles of different durations and bases is the basis for understanding modern global transformations (A Poruchnyk, A. Kolot, P. Mielcarek, Y. Stoliarchuk, and D. Ilnytskyy, 2021). The emergence of crises is often considered as one of the basic stages of economic cycles, their depth and duration are associated with the length, amplitude, depth, balance of the economic cycle, the influence of various endogenous and exogenous factors. At the same time, some studies note the stochasticity of economic processes (O. Bjerkholt & R. Frisch, 1997) and the low predictability of the factors that influence them.

When evaluating different types of models of economic crises, one should also take into account the deep division of research into applied and fundamental. With the use of quite similar tools, the purpose and context of research are completely different, which causes significant differences in the results obtained (V. Gooert and A. Grobler, 2019). Thus, the modeling of socio-economic processes in fundamental research aims to determine the universal principles of the course of processes, in applied research the aim is to find a way to solve individual problems (A. Korobeinikov, 2009). The results of basic research do not have an immediate impact on the development of political and economic decisions, while the results of applied research are immediately implemented. The modeling of economic crises is based on fundamental research, on a deep understanding of the course of socio-economic processes, the regularities of which determine the period of occurrence and the peculiarities of the course of crises. At the same time, the specific manifestations of each crisis determine the need to build applied models that become the basis for choosing methods for overcoming destructive consequences. The vast majority of research is of an applied nature, describing the causes of crisis phenomena in certain economies or sectors.

For the fundamental models of the emergence and development of crises, the use of the Keynesian or liberal paradigm of understanding economic processes is characteristic. Thus, the Keynesian paradigm was based on the dynamic interrelationships of economic and social dimensions, the liberal and neoliberal paradigm uses self-organization and self-maintaining equilibrium of economic development as the main thesis. At the same time, the use of crisis emergence models based on only one of the two paradigms is often ineffective. This is what determines the need to transform the existing paradigm of modeling economic crises. "We are now faced with the need to co-construct with all the actors concerned a new paradigm integrating these specific backgrounds and responding to the new challenges of globalization. It seems that such a dynamic is at work in the European Union (EU) today" (P. Bauby, 2022).

Even though there is a wide variety of groups of models that formalize the factors of occurrence, periodicity, and regularities of the course of economic crises, the main assumption is the existence of a cause-and-effect relationship between certain economic parameters and the occurrence and development of economic crises. The basis of the scientific paradigm of the perception of crisis processes is the thesis of the existence of regularities connecting economic phenomena and processes, the implementation of which determines the inevitability, period, and depth of economic crises.

Taking into account the above information, the purpose of the article was determined - to explain the directions of transformation of the existing paradigm of modeling economic crises. This goal is achieved through the formulation of models for the development of regulations, as is done in H. Rahmandad and N. P. Repenning (2016).

METHODOLOGY

Comparing the parameters of the dynamics of the main macroeconomic indicators is one of the ways to determine their regular nature, which can be caused by the determinism of socio-economic development.

The study included the following stages:

- determining the existence of a cause-and-effect relationship between the evaluated indicators (ΔGDP, ΔE). With the existence of such a cause-and-effect relationship, it would be possible to ascertain the specifics of the deterministic dynamics of one of the indicators as the cause of crises. Initially, it was assumed that the change in the level of employment significantly affects the growth rates of GDP ($\Delta GDP_i(\Delta E_{i-l1})$). A feedback relationship was also possible $\Delta E_i(\Delta GDP_{i-l2})$, where $l1$ and $l2$ are periods of realization of the cause-and-effect relationship between employment growth rates and GDP growth rates ($l1$ for a situation where employment growth rates are the cause, $l2$ for a situation when GDP growth rates are the cause);

- in the absence of a cause-and-effect relationship ΔGDP and ΔE, the following was the determination of the form of their mutually coordinated dynamics and the search for regularities/or the absence of such regularities based on the form of the corresponding dependencies. The existence of regularities $\Delta GDP_i(\Delta E_i)$ of one type will testify to the generality of the mechanism of the emergence of crises;
- research of dependence parameters $\Delta GDP_i(\Delta E_i)$ for the maximum possible number of countries with the search for qualitative regularities in them. At this stage, the methods of function research and cluster analysis (method of finding condensations) were used. The task of applying cluster analysis was to find the grouping of countries according to dependence parameters $\Delta GDP_i(\Delta E_i)$ and to determine the qualitative features of the formation and course of crises in groups;
- determination of moments of crisis phenomena in the national economies of European countries, which did not correspond to dependencies $\Delta GDP_i(\Delta E_i)$. If we consider the co-dependence of GDP growth rates and employment growth rates as the embodiment of the determinism of the dynamics of the development of national economies, then the emergence of crises outside them will mean a contradiction with the existing paradigm of modeling economic crises.

The obtained models relate to only a few aspects of the problem of conceptual explanation of the sources of emergence and development of crises and are highly stylized. However, models used to identify certain patterns do not always have to have all stages of development, as noted by J.D. Sterman (2000).

The growth rates of the gross domestic product per person ΔGDP were chosen as an indicator characterizing the onset and development of crises in European countries. Initially, the volume of GDP production was measured in euros per person based on the average annual population. The data was obtained from the Eurostat website (2021) for the period 1995-2020, after which the corresponding GDP growth rates were calculated for each country. Another indicator, which also comprehensively characterizes the onset/development of crises in the economy, is the indicator of the level of employment and the rates of its dynamics ΔE, taken during the same period. Directly, the pace indicators used in the study cover the period 1996-2020, which makes the sample representative.

RESULTS

Crisis phenomena are natural in the development of the economy of most countries of the world. Taking this into account, it is logical to conclude that the factors causing crises are common in the dominant number of cases. However, the peculiarities of manifestation, the direction of manifestation, and the dynamics of the main macroeconomic indicators during the emergence, course, and end of crises (not referring to crises in local commodity markets, but crises of national economies) create the impression of their uniqueness and inimitability. Of course, it is argued that crises are an element of large macroeconomic cycles, but often the decisive factors of their occurrence take the form of a random event, the significance of which is determined by the institutional and structural imperfections of individual national economies. The combination of regular and random in the formation and development of individual crises has the consequence of affirming their hybrid nature (D. V. Kislov, 2019). Solving the regularity/randomness dilemma in the formation and development of crises in national economies is possible only if a large group of objects forming a relatively homogeneous sample is studied.

We chose the national economies of European countries as such a group of objects, a significant part of which has similar institutional and socio-cultural features of development, a related system of values, and practically free movement of goods and capital. Qualitatively, the national economies of European countries should form a homogeneous group of objects. At the same time, for the vast majority of European countries, it is possible to form a database of statistical data on the main indicators of socio-economic development, the dynamics of which are indicative during the development of crisis phenomena.

The study used data on the dynamics of the specified indicators for the following countries: Austria, Bulgaria, Belgium, Denmark, Estonia, Ireland, Spain, Italy, Cyprus, Latvia, Lithuania, the Netherlands, Germany, Norway, the United Kingdom, Poland, Portugal, Slovenia, Hungary, Finland, France, Croatia, Switzerland, Sweden (twenty-four countries, twenty-three of which are members of the European Union). Statistical data on the development of the economy of the United Kingdom covered the period 1996-2019 since in 2020 statistics from the UK were not transmitted to Eurostat. Individual countries (Greece, Montenegro, Iceland, North Macedonia, Malta, Romania, and Serbia) were also excluded from the study, for which statistical data for the period under consideration were incomplete. The experience of Ukraine was also not considered, since the dynamics of its economic development are not in synergy with the dynamics of the Eurozone countries (G. Kharlamova, A. Stavytskyy, O. Chernyak, V. Giedraitis, and O. Komendant, 2019).

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During the implementation of the first stage of the research, correlation functions were constructed for the interdependencies of indicators $\Delta E_i(\Delta GDP_{i-l2})$ and $\Delta GDP_i(\Delta E_{i-l1})$, when $l1$ and $l2$ varied from 0 to 14. The maximization of these correlation functions gave the value of the maximum correlation when $l1$ and $l2$ were close to zero. Accordingly, the assumption that there is a causal relationship between employment growth rates and GDP growth rates was rejected. However, the correlation at lags close to zero was still strong, which made it possible to assume the existence of a single cause in their coordinated dynamics. J. Varga and J. Veld (2017) also determine the consistency of the dynamics of GDP production and employment in the countries of the eurozone, stating their common dependence on the number of credit resources in the private and public sectors. However, structural changes, such as pension reforms, financial restrictions on obtaining loans, and stimulating investment demand, have the greatest impact on the dynamics of GDP and employment.

The result of the second stage of the research was obtaining a number of dependencies $\Delta GDP_i(\Delta E_i)$ (table 1), which proved that for the vast majority of countries there is a mutual consistency in the dynamics of GDP growth rates and employment growth rates without a shift in time, which is confirmed with a high level of reliability. Insufficient reliability is determined only for countries that were in the zone of influence of the Soviet Union for a long time (Latvia, Lithuania, Croatia) or whose economies suffered significant destruction during the crises of 2008-2010 and 2020 (Netherlands, Portugal, Sweden). The form of almost all of these dependencies (with the exception of Germany and Poland) is parabolic with a maximum point, which indicates the same nature of the influence of the unknown factor on GDP growth rates and employment growth rates in all analyzed European countries. For Poland and Germany, the dependence $\Delta GDP_i(\Delta E_i)$ has the form of a polynomial of the third degree. It is characteristic that the economies of Poland and Germany during the period under consideration were the most stable and had the highest rates of economic growth.

Table 1. Dependence of GDP production growth rates on employment growth rates, $\Delta GDP_i(\Delta E_i)$.

Country	Formal dependency	Reliability	
		F_{fact}	P
Austria	$\Delta GDP(\Delta E) = -0.7305 \cdot \Delta E^2 + 2.9886 \cdot \Delta E - 0.6991$	$7.54 \cdot 10^{-9}$	0.99
Belgium	$\Delta GDP(\Delta E) = -1.5026 \cdot \Delta E^2 + 4.1532 \cdot \Delta E - 1.0037$	$7.67 \cdot 10^{-7}$	0.99
Bulgaria	$\Delta GDP(\Delta E) = -0.3704 \cdot \Delta E^2 + 1.7383 \cdot \Delta E + 4.1995$	$3.66 \cdot 10^{-2}$	0.94
Croatia	$\Delta GDP(\Delta E) = 0.0074 \cdot \Delta E^2 + 0.9593 \cdot \Delta E + 1.4708$	0.652	0.43
Cyprus	$\Delta GDP(\Delta E) = -0.0319 \cdot \Delta E^2 + 1.1124 \cdot \Delta E - 0.4801$	0.189	0.78
Denmark	$\Delta GDP(\Delta E) = -0.3056 \cdot \Delta E^2 + 1.1509 \cdot \Delta E + 0.798$	$6.45 \cdot 10^{-2}$	0.94
Estonia	$\Delta GDP(\Delta E) = -0.1093 \cdot \Delta E^2 + 0.9278 \cdot \Delta E + 4.7607$	$5.39 \cdot 10^{-2}$	0.94
Finland	$\Delta GDP(\Delta E) = -0.3694 \cdot \Delta E^2 + 2.2498 \cdot \Delta E + 0.2169$	$1.33 \cdot 10^{-2}$	0.95
France	$\Delta GDP(\Delta E) = -0.7329 \cdot \Delta E^2 + 3.139 \cdot \Delta E - 0.6429$	0.15	0.72
Germany	$\Delta GDP(\Delta E) = -0.0314 \cdot \Delta E^3 + 0.0788 \cdot \Delta E^2 + 1.6129 \cdot \Delta E - 0.4782$	$4 \cdot 10^{-2}$	0.94
Hungary	$\Delta GDP(\Delta E) = -0.425 \cdot \Delta E^2 + 1.9321 \cdot \Delta E + 2.3153$	$9.6 \cdot 10^{-2}$	0.93
Ireland	$\Delta GDP(\Delta E) = -1.7258 \cdot \Delta E^2 + 0.9947 \cdot \Delta E - 0.008$	$7.3 \cdot 10^{-2}$	0.94
Italy	$\Delta GDP(\Delta E) = -0.4972 \cdot \Delta E^2 + 2.1715 \cdot \Delta E - 0.6128$	$2.7 \cdot 10^{-2}$	0.95
Spain	$\Delta GDP(\Delta E) = -0.0101 \cdot \Delta E^2 + 0.9077 \cdot \Delta E - 0.3436$	$8.58 \cdot 10^{-2}$	0.93
Latvia	$\Delta GDP(\Delta E) = -0.151 \cdot \Delta E^2 + 0.3148 \cdot \Delta E + 1.4948$	0.91	0.42
Lithuania	$\Delta GDP(\Delta E) = -0.2966 \cdot \Delta E^2 + 0.5208 \cdot \Delta E + 2.5151$	0.84	0.42
Netherlands	$\Delta GDP(\Delta E) = -0.049 \cdot \Delta E^2 + 1.3952 \cdot \Delta E - 0.4759$	0.107	0.68
Norway	$\Delta GDP(\Delta E) = -0.1349 \cdot \Delta E^2 + 0.9082 \cdot \Delta E + 0.3013$	$7.3 \cdot 10^{-2}$	0.94
Poland	$\Delta GDP(\Delta E) = -0.0533 \cdot \Delta E^3 + 0.2053 \cdot \Delta E^2 + 0.8313 \cdot \Delta E + 2.5954$	$2.09 \cdot 10^{-2}$	0.94
Portugal	$\Delta GDP(\Delta E) = -0.0179 \cdot \Delta E^2 + 1.207 \cdot \Delta E - 0.313$	0.352	0.58
Slovenia	$\Delta GDP(\Delta E) = -0.0794 \cdot \Delta E^2 + 0.7221 \cdot \Delta E + 1.8598$	0.124	0.72
Switzerland	$\Delta GDP(\Delta E) = -0.2295 \cdot \Delta E^2 + 1.5454 \cdot \Delta E - 0.491$	$5.26 \cdot 10^{-2}$	0.94
Sweden	$\Delta GDP(\Delta E) = -0.4305 \cdot \Delta E^2 + 1.3993 \cdot \Delta E + 1.2522$	0.276	0.60
the United Kingdom	$\Delta GDP(\Delta E) = -0.5486 \cdot \Delta E^2 + 2.242 \cdot \Delta E - 0.0591$	0.111	0.74

The next task of the research was to determine the parameters of the functions $\Delta GDP_i(\Delta E_i)$ and their grouping according to the convergence of these parameters. Three main parameters of the functions were calculated - the extremum point $\Delta GDP_i^{|}(\Delta E_i) = 0$ and the point of intersection of the functions with the axis x $\Delta GDP_i(\Delta E_i) = 0$ was determined (table 2).

The economic content of the extremum for the functions $\Delta GDP_i(\Delta E_i)$ corresponds to the growth rate of population employment at which the GDP growth rate is maximum/minimum. At the points $\Delta GDP_i(\Delta E_i) = 0$, the sign changes $\Delta GDP_i(\Delta E_i)$, so their values are critical, at which GDP growth rates become negative.

Table 2. Clustering European countries by function parameters $\Delta GDP_i(\Delta E_i)$.

Country	Critical level of employment growth, %		Optimal level of employment growth	
	minimum, ΔE_{min}	maximum, ΔE_{max}	value of the optimal employment growth rate, %, ΔE_{ext}	maximum possible GDP growth rate, %, ΔGDP_{max}
cluster 1				
Estonia	-0.277	0.330	0.097	0.064
Ireland	0.032	0.568	0.288	0.115
Lithuania	-8.654	3.919	0.879	2.286
Latvia	-9.088	4.356	1.042	1.330
cluster 2				
Austria	0.996	3.842	2.045	3.755
Belgium	1.070	2.496	1.382	3.873
Denmark	-2.393	4.364	1.883	0.285
Netherlands	0.584	2.451	1.423	1.462
United Kingdom	0.106	4.060	2.043	2.349
Spain	0.044	2.630	1.320	0.609
Sweden	-2.922	3.981	1.625	0.115
cluster 3				
Bulgaria	-7.075	9.408	2.319	2.206
Italy	1.213	4.064	2.183	2.983
Hungary	-3.939	5.531	2.273	0.119
France	0.862	4.067	2.141	4.003
cluster 4				
Norway	-1.267	7.049	3.366	1.227
Portugal	1.041	6.716	3.371	2.066
Finland	-0.379	6.185	3.045	3.208
Switzerland	1.337	6.399	3.366	3.092
cluster 5				
Slovenia	-8.374	11.188	4.547	0.218
cluster 6				
Cyprus	1.748	34.434	17.435	10.177
cluster 7				
Croatia	-11.186	-7.106	–	–
cluster 8				
Germany		5.066	0.836	0.923
Poland		3.900	1.283	2.265

A total of seven clusters of European countries were identified:

- the first cluster includes countries that demonstrate low rates of economic growth (both ΔGDP , and ΔE), whose economies have been in a state of depression for a long time and are currently entering the stage of cautious economic growth (Estonia, Ireland, Lithuania, Latvia). The economy of these countries has no structure-forming importance for the economy of the European Union as a whole;

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- the second cluster is formed by dominant countries in terms of economic growth rates (Austria, Belgium, Denmark, Spain, the Netherlands, the United Kingdom, Sweden). All these countries are characterized by being at the stage of economic growth during 1995-2020, but at the end of the specified period, their economic growth rates decrease sharply. Therefore, quite significant rates of growth in the level of employment coincide with insignificant rates of GDP growth;
- in the third cluster there are countries that demonstrate stable growth in terms of employment growth rates (Bulgaria, Italy, Hungary, France), but GDP growth rates are variable and insignificant compared to other European countries. The qualitative difference between the countries of the fourth cluster (Norway, Finland, Switzerland, Portugal) and the countries of the third cluster lies in significantly higher growth rates - both in terms of GDP and employment. The countries of the second, third, and fourth clusters are distinguished by the fact that they are currently at the stage of economic growth, but the period when the growth rates were the highest has already passed;
- the countries of the fifth (Slovenia), sixth (Cyprus) and seventh (Croatia) clusters have unique dependencies $\Delta GDP_i(\Delta E_i)$, which differ significantly from the typical dependency's characteristic of the first-fourth clusters. In particular, Slovenia has a wide range of $\Delta E_{min} - \Delta E_{max}$, within which potential GDP growth is negligible. For Cyprus, the dependence $\Delta GDP_i(\Delta E_i)$ is characterized by both the width of the range $\Delta E_{min} - \Delta E_{max}$, and the high value of ΔE_{ext} , which is tens of times higher than the corresponding values for other countries. For Croatia, the dependency $\Delta GDP_i(\Delta E_i)$ is characterized by the existence of an extremum-minimum, which is unique among the corresponding dependencies for other European countries;
- for the countries of the seventh cluster (Germany, Poland), as mentioned above, the dependence $\Delta GDP_i(\Delta E_i)$ is polynomial (of the third order), which means the existence of two extremes. Dependencies $\Delta GDP_i(\Delta E_i)$ are characterized both by the existence of an extremum-maximum (the point of optimal employment growth rates) and the limit of positive employment growth rates (+5.067% for Germany and +3.9% for Poland), exceeding which causes a drop in GDP.

At the fourth stage of the research, it was determined that for the majority of European countries, the crisis manifestations in their economies were mainly realized in a similar way. The entire population of the studied countries can be divided into three main groups:

- group 1, which is characterized by the fact that all crisis manifestations in the economy were implemented within the limits of the identified dependencies $\Delta GDP_i(\Delta E_i)$. This group includes the vast majority of countries - Bulgaria, Denmark, Estonia, Ireland, Cyprus, the Netherlands, Poland, Portugal, France, Croatia, Hungary, Switzerland, and Sweden (thirteen of the twenty-four studied countries). Falling GDP and/or decreasing employment in these countries during the known crisis periods of 2008-2010 and 2020, when the destructive impact of negative external factors was particularly strong, did not go beyond their cyclical dynamics. For most of these countries, the level of public debt was less than 60% of GDP (Bjerkholt, O., & Frisch, R., 1997);
- group 2 which is characterized by only one period when crisis manifestations in the economy were realized outside the limits of the identified dependencies $\Delta GDP_i(\Delta E_i)$. This group includes the countries of Austria, Belgium, Spain, Italy, Germany, the United Kingdom, and Finland (seven of the twenty-four countries studied). Mostly such a period is 2008 or 2009 when the negative destructive influence of the global financial crisis was most strongly realized. The level of public debt in these countries mostly exceeded 60% of GDP (Bjerkholt, O., & Frisch, R., 1997). The negative phenomena in the economy that arose as a result of the corona crisis in 2020 did not go beyond the identified dependencies $\Delta GDP_i(\Delta E_i)$. For the countries of this group, the economic losses during the crisis were not as significant as it was expected according to the forecast of the World Bank (Yu. Lola, 2021);
- group 3, which is characterized by a significant number of exceptions, when almost all crisis manifestations in the economy occur outside the boundaries of the identified dependencies $\Delta GDP_i(\Delta E_i)$. This group includes Latvia, Lithuania, Norway, and Slovenia. However, three countries from this group are characterized by a relatively low level of reliability of the revealed patterns of GDP growth dynamics and the level of employment (Latvia, Lithuania, Slovenia), which may explain a significant number of deviations. What is more interesting is that for Norway there was a long period when GDP growth rates were negative (albeit in a small way) - 2008, 2009, 2010, 2011, and 2013. At the same time, there was often a slight reduction in the level of employment.

The repeatability of the dynamics of GDP growth rates and employment growth rates was also investigated independently of each other, since no cause-and-effect relationships between them were found (table 3).

Table 3. Variability and repeatability of GDP production growth rates on employment growth rates, $\Delta GDP_i(\Delta E_i)$.

Country	Coefficient of variation	Duration of periods of self-similarity, years	
		ΔGDP_i	ΔE_i
Austria	1.597	11	11
Belgium	0.646	11	11
Bulgaria	-0.600	12	12
Croatia	2.354	12	11
Cyprus	1.039	–	12
Denmark	-1.319	10	14
Estonia	2.131	11	11
Finland	-6.927	–	11
France	3.258	11	–
Germany	3.653	11	17
Hungary	-2.182	11	–
Ireland	-2.356	–	–
Italy	-4.542	11	–
Spain	-1.224	11	–
Latvia	-2.954	–	10
Lithuania	-1.744	11	10
Netherlands	6.659	10	10
Norway	6.118	10	10
Poland	0.700	11	10
Portugal	-1.942	10	–
Slovenia	-3.507	12	–
Switzerland	1.032	–	–
Sweden	-6.624	–	–
the United Kingdom	1.266	–	–

The study was conducted by constructing autocorrelation functions, as the statistics were not detailed enough to determine the persistence and topological dimension of the dynamics. Usually, the results are quite approximate, but it was found that the coincidence of periods of self-similarity for ΔGDP_i and ΔE_i is rather an exception than a rule. For the entire group of studied countries, the determined duration of periods of self-similarity varies from 10 to 17 years; in 17 cases, out of 46 data series it is not determined at all. The latter does not mean at all that the same similarity does not exist since the periods of the same similarity can be much longer or are not determined with a sufficient level of reliability at a given time period. Differences in the duration of periods of similarity also mean that the patterns of dynamics of GDP growth rates and employment growth rates are contingent. As a result of their contingency, a periodic coincidence of potential moments of breaking trends is quite likely, which can be a prerequisite for the emergence of crises. It was not possible to determine certain regularity in the duration of periods of self-similarity by clusters of European countries.

In general, the most vivid crisis trends appeared in Europe in the period 2009-2010 (S. S. Patsykivskyi, 2010), and 2009 was the most critical year. It was in 2009 that the largest drop in the real sector of the economy, predicted by the OECD, was realized. However, the economic downturn caused by the COVID-19 pandemic had significant negative consequences for most of the national economies of the world. At the same time, these consequences are prolonged for long time intervals. Against the background of negative expectations of the World Bank at the beginning of 2020 (World Bank, 2021), the slowdown in GDP growth seems even more significant and may mean the premature onset of a global financial and economic crisis.

The onset of this crisis seems inevitable given the already existing and expected consequences of Russia's aggressive war against Ukraine. Thus, according to OECD data (2022), the expected annual inflation in European countries has increased to 7.7% (1.7% in 2021). Inflation of energy prices in February 2022 amounted to 26.6%, food prices – 8.6%, and prices of other goods – 5.5%, which significantly exceeds any peacetime expectations. The number of refugees from Ukraine in February-March 2022 amounted to more than 3.063 thousand people. For comparison, in 2020, 472.000 people applied

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for international protection in the countries of the European Union. On a global scale, GDP is expected to decrease by more than 1% (for European countries - almost 1.5%), and another 2.5% may be added to the expected inflation. In addition, an unpredictable but significant manifestation of the crisis in the food, energy, and metal markets which will negatively affect a wide range of industries, such as aircraft construction, mechanical engineering, electronics manufacturing, etc.

DISCUSSION

The results of the study have caveats:

- from the results of the study, a number of countries were excluded, in which the manifestation of crisis phenomena was the most vivid (Greece, Montenegro, Iceland, North Macedonia, Malta, Romania, Serbia) and, previously, had a decentralized character. In particular, for a number of countries that were under the influence of the Soviet Union, crisis phenomena were caused by the transformation of the institutional foundations of society. Therefore, for the completeness of the research, it is necessary to identify the significance of determinism in the formation and course of crises in these countries;
- in connection with the close cooperation of the economies of the European Union countries, the specific regularities of the dynamics of the development of individual national economies are smoothed out. This reduces the effectiveness of determining the impact of random factors on the emergence and development of crises.

When interpreting the results of the study, we took into account that "when the goal is to generalize, data on a specific case can even be misleading, because "the particular curves of past history are only a special case" (J. W. Forrester, 2007).

In general, the dynamics of selected macroeconomic indicators by European countries is not deterministic and is interdependent. Therefore, the periodic repetition of macroeconomic indicators falls out of the existing paradigm of the existence of regularities that connect economic phenomena and processes and determine the formation and development of crises. At the same time, the repeatability of the dynamics of macro indicators exists and has signs of similarity. This gives grounds for the emergence of a hypothesis about the fractal nature of the dynamics of economic processes and their contingency. There are partial confirmations in separate scientific works. In particular, the publication of O. Scorba, T. Pasco, V. Babenko-Levada, and T. Tereshenko (2021) asserts the fractal-like nature of the dynamics of the volume of tax revenues in Ukraine and the negative production of entropy in periods of crises. At the same time, the authors claim the existence of types of taxes within which the patterns of dynamics are similar. V. Babenko-Levada (2021) asserts the fractal similarity and contingency of the dynamics, researching indicators of the development of the insurance market of Ukraine. The work (O. Hrabchuk, 2020) also confirmed the fractal-like nature of price index dynamics in the economy of Ukraine, the negative production of entropy in periods of crises, and the existence of the scale effect.

Therefore, it is expedient to conduct a number of studies on the formation and development of crisis processes within the new paradigm - the patterns of economic processes and phenomena are fractal-like, and the factor for the emergence of crises is the contingent coincidence of periods of negative entropy production according to several characteristics of the development of economic systems. The immediate "switch" of the crisis is a "black swan" type event, which is completely random. Verification of the effectiveness of an alternative paradigm for modeling economic crises should consist in confirming the self-sufficiency of their dynamics, confirming or refuting its stochasticity, and checking the coincidences of breaking contingent laws of dynamics, namely:

- confirmation of the fractal similarity of the dynamics of economic processes;
- confirmation for economic characteristics of negative entropy production in periods of crises and their contingent coincidence;
- determination of the effect of scale in the dynamics of economic processes. The latter will manifest itself first of all as an increase in the chaotic dynamics with an increase in the frequency of measurements.

Determining the nature of the origin of certain crises determines the way to counteract their negative consequences. In particular, the consequences of the financial crisis of 2008 (A. Kriwoluzky, 2020) were minimized due to the fact that the central banks of the countries ensured the liquidity of assets, which caused a decrease in interest rates and, ultimately, increased demand. Moreover, the Fed implemented measures to improve liquidity much faster than the European Central Bank. Measures to overcome the consequences of the 2020-2021 crisis were implemented much faster. In addition to stimulating demand by lowering interest rates, they also included actions by national governments regarding the population's access to support funds and subsidies.

Such situational tools for overcoming crises, which are not of a systemic nature, but rather caused by external destructive factors, will not be sufficiently effective in the event of the onset of deep non-deterministic crises. The joint implementation of tools to stimulate the development of economies, as in the countries of the European Union, may not be effective enough. It is the solidary development of the economy that carries additional threats when approaching systemic crises when the synchronization of destructive processes can intensify them. At the same time, the negative impact of external threats (such as, for example, Russia's aggression against Ukraine and a significant increase in the price of energy resources) in case of synchronization of crisis processes, will significantly accelerate them and make them deeper.

CONCLUSIONS

Modeling of economic crises according to the existing paradigm of perceiving economic processes as deterministic does not provide sufficiently reliable and repeatable results, which not only determines the need to improve the methodology of building models but also calls into question the completeness of the paradigm. The obtained results of modeling the relationship between GDP growth rates and employment growth rates for 24 European countries for the period 1996-2020 deny the existence of a cause-and-effect relationship between them since the action lag between the specified characteristics is zero. However, there is still a dynamic interdependence between the specified characteristics, which for the vast majority of countries is polynomial of the second order and is confirmed with a high level of reliability. The range of changes in employment growth rates has a quantitative correspondence with the range of changes in GDP growth rates. The parameters of the interdependencies of the dynamics of GDP growth rates and the growth rates of the employment level made it possible to form eight clusters of European countries in which the quantitative patterns of the manifestation of crisis phenomena are similar. The internal division of the Eurozone countries according to the parameters of the dependence of the GDP growth rates and the growth rates of the employment level gave reasons to state the lack of strict structuring of the Eurozone economy as a systemic entity.

In addition, there is the repeatability of the dynamics of GDP growth rates and employment rate growth rates with significant differences in the length of the recurrence periods and a significant variation of deviations from the line of formalization of their co-dependence. These results and the results of previous studies provide grounds for formulating an alternative paradigm for modeling crisis processes. Within this paradigm, the relationship between economic characteristics is not deterministic, the laws of their dynamics are contingent and self-similar, and the basis for the emergence of crises is the coincidence of periods of breaking trends in a significant number of socio-economic processes. Direct drivers of crises arise as random events against the background of systemic prerequisites for shifts in the contingent regularities of partial self-similar dynamics of economic processes.

Based on an alternative paradigm, the modeling of economic crises should consist in the study of the very similarity, contingency, and dissipativeness of the dynamics of economic indicators, which fully corresponds to the principles of the theory of evidence in the system of scientific knowledge - simplicity, inductance, simplification and expansion of the range of data.

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ТРАНСФОРМАЦІЯ ПАРАДИГМИ МОДЕЛЮВАННЯ ЕКОНОМІЧНИХ КРИЗ

Для розробки обґрунтованих заходів щодо протидії деструктивним наслідкам економічних криз чи їх попередження важливою є побудова обґрунтованих адекватних моделей виникнення та перебігу кризових процесів. Формальна відповідність існуючих моделей соціально-економічним процесам у період кризи часто є неповною або не може бути адаптована до інших умов, економік, ринків. Відтак стаття присвячена доцільності й можливості трансформації існуючої парадигми моделювання економічних криз.

Моделювання співзалежності двох базових показників, які характеризують кризовість розвитку економіки країн Європи (темпів зростання ВВП та темпів зростання зайнятості), спростувало можливість їх взаємної детермінації. Співзалежність динаміки темпів зростання ВВП та темпів зростання зайнятості за всіма досліджуваними об'єктами без зміщення в часі, визначена за період 1996-2020 рр. із високим рівнем достовірності, є однотиповою та дала змогу визначити діапазон їхніх взаємних змін. За цим діапазоном та параметрами співзалежностей темпів зростання ВВП та темпів зростання зайнятості методом пошуку згущень визначено вісім кластерів країн. Виникнення кризових процесів збігається зі специфічними параметрами співзалежної динаміки темпів зростання ВВП та темпів зростання рівня зайнятості, однак не пов'язане із внутрішнім поділом країн Єврозони на кластери.

Отримані результати дали підставу висунути альтернативну парадигму моделювання кризових процесів, відповідно до якої економічні кризи виникають унаслідок упливу випадкових деструктивних подій на системні збіги потенційних періодів зрушень у контингентних закономірностях часткових самоподібних динамік економічних процесів. У межах цієї парадигми моделювання економічних криз та прогнозування їх настання буде ґрунтуватись на дослідженні самоподібності, дисипативності та контингентності динамік економічних процесів.

Ключові слова: економічна криза, детермінованість, стохастичність, моделювання, контингентність, динаміка, темпи зростання ВВП, темпи зростання зайнятості

JEL Класифікація: E17, O47, C01