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A HIERARCHICAL SYSTEM OF MARKET SIGNALS FOR EARLY DIAGNOSIS OF FINANCIAL CRISES

ІЄРАРХІЧНА СИСТЕМА РИНКОВИХ СИГНАЛІВ ДЛЯ РАННЬОЇ ДІАГНОСТИКИ ФІНАНСОВИХ КРИЗ

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The article examines the problem of early diagnosis of financial crises as an important direction of ensuring the stability of financial systems in the conditions of growing global instability. The purpose of the study is to develop an analytically substantiated system of market signals for early detection of periods of increased financial stress, which may precede crisis phenomena and destabilization of financial markets. The scientific novelty of the study lies in the formation of the concept of a hierarchical system of market signals for early diagnosis of financial crises, which combines simplicity of calculations, economic interpretability and practical suitability for regular monitoring of financial stability. The practical significance of the results obtained lies in the possibility of using the proposed system of signals to support preventive management decisions and further development of integral indicators of financial stress.

Keywords: financial crises, early diagnosis of crises, market signals, financial instability, market volatility, financial stress, financial markets.

У статті досліджено проблему ранньої діагностики фінансових криз як важливого напряму забезпечення стійкості фінансових систем в умовах зростання глобальної нестабільності. Метою дослідження є розробка аналітично обґрунтованої системи ринкових сигналів для раннього виявлення періодів підвищеної фінансової напруги, що можуть передувати кризовим явищам і дестабілізації фінансових ринків. Для досягнення поставленої мети узагальнено наукові підходи до раннього попередження фінансових криз, обґрунтовано концепцію ринкових сигналів як інструменту виявлення зміни режимів функціонування фінансового ринку, сформовано набір ключових індикаторів фінансової нестабільності та запропоновано принципи їх інтерпретації в межах ієрархічної аналітичної системи. Теоретичною основою дослідження виступає режимний підхід до аналізу фінансових ринків, відповідно до якого динаміка ринку розглядається як послідовність переходів між станами стабільності, фінансової напруги та кризи. Емпірична частина дослідження базується на використанні щоденних часових рядів фінансових показників, які відображають динаміку основних сегментів глобального фінансового ринку протягом тривалого періоду спостережень. У роботі доведено, що окремі індикатори не завжди забезпечують однозначну інтерпретацію передкризових процесів, тому більш надійним є їх комбіноване використання. Наукова новизна дослідження полягає у формуванні концепції ієрархічної системи ринкових сигналів для ранньої діагностики фінансових криз, яка поєднує простоту розрахунків, економічну інтерпретованість і практичну придатність до регулярного моніторингу фінансової стабільності. Запропонований підхід створює аналітичну основу для виявлення передкризових станів без застосування надмірно складних економетричних моделей та розширює можливості макропруденційного аналізу. Практичне значення одержаних результатів полягає в можливості використання запропонованої системи сигналів для підтримки превентивних управлінських рішень, підвищення готовності економічних агентів до можливих «шоків» і подальшого розвитку інтегральних індикаторів фінансової напруги.

Ключові слова: фінансові кризи, рання діагностика криз, ринкові сигнали, фінансова нестабільність, волатильність ринку, фінансова напруга, фінансові ринки.

Statement of the problem. Financial crises are an integral part of the development of the global economic system and are cyclical, arising at different stages of its functioning. Their occurrence is usually associated with the accumulation of structural imbalances, the

growth of the debt burden, the intensification of speculative operations in financial markets and the imperfection of state regulation mechanisms. This causes destabilization of the financial environment, which negatively affects the activities of economic entities and macroeconomic dynamics.

Typical manifestations of financial crises are sharp fluctuations in the value of assets, a reduction in lending and a deterioration in access to liquid resources. Such processes lead to a decrease in investment activity, a decrease in production and employment, as well as a deterioration in the socio-economic situation of the population.

During the exacerbation of crises, the level of systemic risk increases and the interdependence between financial institutions, markets and national economies increases. As a result, even local imbalances can quickly spread through transmission channels, which creates a «chain reaction» effect and complicates the application of traditional macroeconomic stabilization tools.

Under such conditions, the development of approaches to early detection of financial instability becomes particularly important. The formation of early warning systems and the use of analytical indicators make it possible to respond in a timely manner to the accumulation of risks, increase the stability of financial systems and ensure more effective management decision-making.

Analysis of recent research and publications. The issue of financial crises and mechanisms for their early detection is actively studied in modern economic science. A significant number of works are devoted to the development of early warning systems that allow identifying the accumulation of financial imbalances and increasing systemic risk long before the onset of crisis events.

One of the fundamental works in this area is the study by Kaminsky and Reinhart [1], which proposed the so-called signal approach for forecasting currency crises. The authors showed that a number of macroeconomic and financial indicators demonstrate anomalous behavior in the periods preceding crises and can be used as a system of early warning signals. Within the framework of this approach, exceeding the threshold value of the indicator is considered as a signal of a potential crisis in subsequent periods.

Further development of this methodology is presented in the work of Reinhart and Rogoff [2], where an empirical analysis of the relationship between macroeconomic imbalances, banking and currency crises was carried out. These studies show that financial crises usually develop gradually due to the accumulation of vulnerabilities in the financial system, which can be detected using early warning indicator systems.

An important contribution to the development of approaches to the analysis of systemic financial risks was made by Borio and Drehmann [3–5], who studied the role of the financial cycle and credit expansion in the formation of crisis processes. Their studies showed that a significant increase in private sector lending and asset prices often precedes banking crises and can be used as an effective early indicator of financial instability.

In subsequent works, extended systems of financial vulnerability indicators were proposed. In particular, Aldasoro et al. [6] studied the role of debt ratios and international financial flows as early indicators of banking crises, showing that the growth of the debt burden and financial dependence of economies can be an important signal of the accumulation of systemic risks.

Another area of research is related to the use of econometric models and statistical methods to predict crisis events. In particular, Edison [7] assessed the effectiveness of various indicators of financial crises and proposed approaches to building applied early warning systems based on macroeconomic variables.

The modern literature also considers more complex models of financial instability analysis. For example, the study by Caggiano, Calice and Leonida [8] is devoted to the use of econometric models to predict banking crises in different countries, and the work of Babecky et al. [9] analyzes systemic banking crises based on a large panel database covering several decades of financial market development.

At the same time, modern research emphasizes that many early warning models are characterized by considerable complexity, require a large amount of data and regular recalibration of parameters. In this regard, there is a growing interest in more analytically interpreted approaches in the scientific literature, which are based on the use of a set of key market indicators and allow for regular monitoring of financial stability.

Thus, despite a significant amount of research in the field of early detection of financial crises, the task of developing analytically transparent and practically applicable indicator systems capable of recording the gradual accumulation of

financial stress at different stages of the financial cycle remains relevant.

Highlighting previously unresolved parts of the overall problem. In the anti-crisis management system, the key is not so much determining the exact date of the onset of a financial crisis, but rather timely detection of the transition of the financial system to a state of increased instability and its increased vulnerability to internal and external «shocks».

This approach is explained by the complex nature of crisis processes, which are formed under the influence of interrelated macroeconomic, institutional and behavioral factors [10]. Their interaction causes the accumulation of risks and can lead to the effect of mutual reinforcement of these risks [11]. As a result, determining the exact moment of the crisis is a methodologically difficult task, since the results of the analysis largely depend on the choice of model, set of indicators, time lags and assumptions about the behavior of economic agents.

Therefore, modern research is increasingly focusing on early diagnosis of financial instability, which involves the detection of pre-crisis or stress states. Such states are characterized by increased volatility, deterioration of liquidity, increased credit risks and a general increase in financial tension. Detecting such signals at an early stage allows for timely application of preventive measures, in particular, adjusting the asset structure, hedging risks and strengthening macroprudential regulation.

At the same time, modern economic science offers a wide range of models for analyzing and forecasting the dynamics of financial markets, but their practical application in continuous monitoring systems is often accompanied by a number of methodological limitations. Many models are characterized by significant computational complexity, require significant resources for data processing, as well as careful parameter tuning and regular recalibration. In addition, the modeling results may be sensitive to changes in the sample, frequency of observations or set of variables.

An additional problem is the limited transparency of complex analytical models, which complicates their interpretation and use in the practice of strategic management and regulatory control. In view of this, there is growing interest in approaches aimed at developing a simpler and analytically interpretable system of indicators suitable for regular monitoring of financial stability and early detection of periods of increased financial stress [12].

Formation of the objectives of the article (task statement). The aim of the research is to develop an analytically sound and practically applicable system of market signals for early detection of periods of increased financial stress that may precede crisis phenomena and destabilization of financial markets. The implementation of such an approach is aimed at timely detection of risk accumulation, increasing the readiness of economic agents to possible «shocks» and ensuring the adoption of preventive management decisions.

To achieve this goal, the following interrelated tasks are envisaged:

to substantiate the concept of market signals and the mechanism of the financial system's transition between different states of its functioning and to determine the role of indicators in recording changes in systemic risk;

to form a set of quantitative indicators that reflect key manifestations of increased financial vulnerability, in particular increased volatility, worsening liquidity and increased correlations between assets;

to develop principles for interpreting indicators and combining them into a comprehensive assessment system to increase the reliability of signals and reduce the likelihood of false signals.

The scientific novelty of the study lies in the formation of the concept of a hierarchical system of market signals, which classifies indicators of financial instability at three levels - primary symptoms, systemic signals and crisis signals. The proposed approach allows interpreting the growth of financial tension as a sequential process of market transition between different modes of functioning.

Summary of the main research material. The financial market should be considered as a complex, open and dynamic system, the development of which is determined by the interaction of numerous internal and external factors [13]. In this approach, market dynamics are interpreted not as a sequence of individual events, but as a change in operating modes that differ in the level of risk, the degree of stability and the behavioral characteristics of participants.

A stable market state is characterized by relatively low volatility, a predictable structure of correlations between assets and a sufficient level of liquidity. Under such conditions, investor behavior is more rational, and fluctuations in market indicators remain within the limits of normal statistical deviations.

The phase of financial stress is formed gradually due to the accumulation of macroeconomic

and financial imbalances, the intensification of speculative operations and the growth of the debt burden. During this period, the market becomes more sensitive to information signals, asset price volatility increases, the structure of correlations between financial instruments changes, and the behavioral reactions of participants intensify.

The crisis regime is accompanied by a sharp destabilization of the market environment: a rapid decline in asset values, a significant increase in volatility, increased interdependence between market segments and increased demand for liquidity. Such processes can spread rapidly and cause large-scale systemic disruptions.

Within such a regime approach, the key task of early warning systems is to identify the moment of transition of the financial market from stability to a phase of increased tension, when systemic risk is formed and the probability of crisis processes increases.

Pre-crisis periods have a number of typical features that are manifested in market data and can be considered as symptoms of increasing financial tension. To build a practical early warning system, it is advisable to use indicators that are regularly observed, have a clear economic interpretation and reflect the key mechanisms of risk accumulation.

Within the framework of this study, the main symptoms are increased volatility, increased trading activity and increased synchronicity of financial asset movements.

Volatility reflects the level of uncertainty about future price dynamics and is a basic characteristic of the risk of financial assets. In pre-crisis periods, it usually increases due to the instability of expectations and increased market sensitivity to information «shocks». For practical monitoring, it is advisable to use simple indicators, in particular, the moving standard deviation of asset returns.

Trading activity characterizes the intensity of portfolio redistribution and changes in investors' behavioral strategies. The growth of trading volumes may be associated with a review of risk positions, forced closing of transactions, or increased demand for liquidity, which indicates a change in market expectations.

Another sign of crisis periods is the increased synchronicity of price movements between different assets and segments of the financial market. In stable conditions, correlations remain moderate, ensuring the effectiveness of diversification. However, in stressful situations, the phenomenon of convergence of correlations occurs when investors simultaneously reduce risk positions, which increases the systemic nature of the risk.

Thus, the theoretical basis for building a market signals system is based on a regime approach to the analysis of financial markets and the identification of typical signs of pre-crisis conditions. The selection of indicators in the study is carried out according to the following principles:

– simplicity and reproducibility of calculations;

– understandable economic interpretation of the results;

– reflection of three key manifestations of financial stress: volatility, trading activity and synchronicity of asset movements;

– the possibility of presenting the results in a signal/non-signal format for use in early warning systems.

Empirical basis of the study. The empirical part of the study is based on the use of daily time series of financial indicators that reflect the dynamics of the main segments of the global financial market. The use of high-frequency data allows for a more accurate capture of short-term fluctuations, changes in volatility and behavioral reactions of investors, which is important for identifying periods of increased financial tension.

To ensure the representativeness of the study, an observation period of about ten years is used. This time interval covers both relatively stable stages of financial market development and phases of increased turbulence caused by global or regional «shocks». The presence of different modes of financial market functioning in the sample allows us to assess the ability of the indicator system to capture transitions between them.

The analytical base includes several groups of indicators that reflect different channels of financial risk manifestation and investor reactions:

1. Stock market. Represented by the S&P 500 index, which reflects the overall dynamics of the stock market and aggregates investors' expectations regarding economic growth, corporate earnings and the level of risk.

2. Volatility. Represented by the VIX index, which characterizes the expected market volatility and the level of uncertainty. The growth of this indicator usually accompanies periods of increased market tension.

3. Currency segment. Represented by the US Dollar Index, which reflects changes in global capital flows and demand for liquidity.

4. Protective assets. This category includes gold, which traditionally performs the function of a store of value and often demonstrates alternative dynamics compared to risky assets.

5. Bond market. Represented by the yield on long-term US government bonds (US 10Y Treasury Yield), which reflects financing conditions and expectations regarding the economic cycle and monetary policy.

The use of these indicators allows for a comprehensive coverage of various aspects of financial instability - from changes in market expectations and volatility to the reallocation of capital between risky and protective assets.

Financial crises, as a rule, are formed gradually due to the accumulation of imbalances and the growth of systemic vulnerability of financial markets [14]. This process is accompanied by the emergence of signals reflecting changes in market conditions, in particular, increased volatility, changes in the level of trading activity, increased correlations between assets or increased demand for protective instruments. At the same time, individual indicators do not always allow for an unambiguous interpretation of the approach of crisis processes, since their dynamics may be due to short-term fluctuations or local events.

In view of this, it is advisable to analyze market signals within the framework of a structured analytical system, which allows them to be assessed in the context of a gradual increase in financial instability. This study proposes the concept of a hierarchical system of market signals, which involves classifying indicators by levels depending on the scale of risk spread in the financial system.

Construction of a hierarchical system of market signals. The proposed hierarchical system allows us to consider the development of a financial crisis as a gradual process within which the market moves from local changes to systemic instability and the crisis phase. For clarity, the structure of the relationship between different levels of market signals is presented in Fig. 1.

Within the framework of the proposed concept, the development of crisis processes is considered as a gradual transition between different levels of signals:

primary market symptoms → systemic signals → crisis signals.

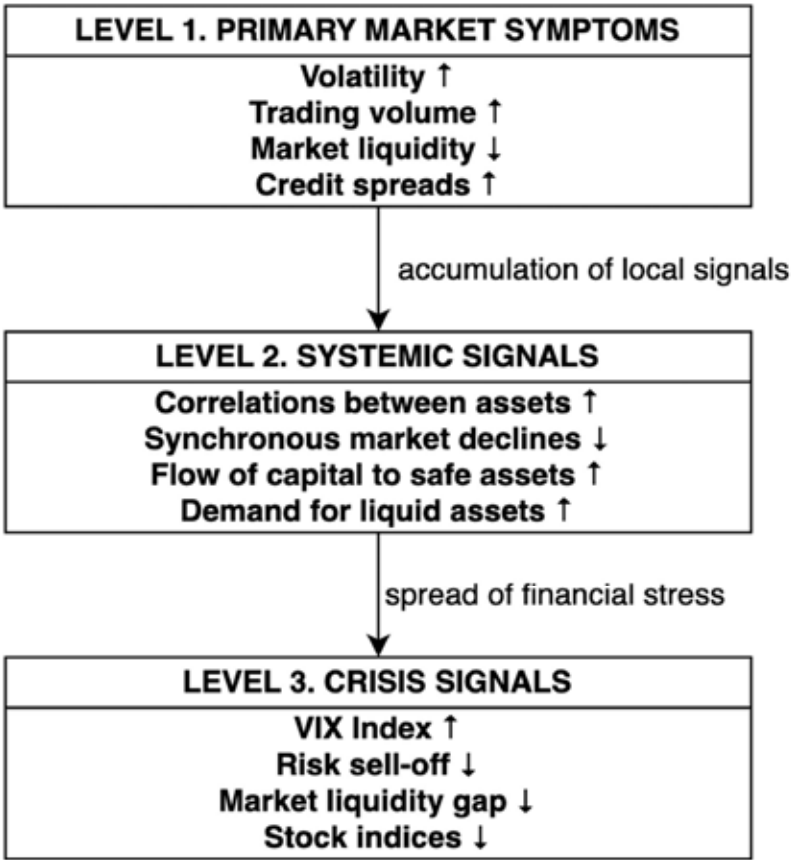

Figure 1. Escalation of market signals of financial stress

Source: created by the author

At the initial stages, the market demonstrates only individual local changes that may be associated with short-term fluctuations or corrections. Over time, these phenomena spread between different segments of the financial market, which is manifested in the formation of systemic signals of increased risk. Further intensification of such processes leads to the appearance of crisis signals that reflect the market transition to a phase of high turbulence.

Thus, the concept of a hierarchical system of market signals allows us to consider financial instability as a step-by-step process of stress accumulation, within which various indicators act as interconnected elements of a single analytical model. This approach creates the basis for the formation of practical early warning systems and increases the possibility of timely detection of pre-crisis conditions in financial markets.

To systematize market indicators, the study proposes a hierarchical structure of financial stress signals (Table 1).

The proposed classification allows us to consider financial instability as a sequential process in which local symptoms gradually transform into systemic signals, and subsequently into crisis manifestations. This logic reflects the evolution of financial stress from initial changes in the behavior of market participants to large-scale destabilization processes. The use of a hierarchical structure of signals creates an analytical basis for building early warning systems and facilitates the interpretation of changes in market indicators at different phases of the financial cycle.

The hierarchical classification of signals involves not only their division by levels, but also the definition of rules for practical interpretation. Since individual indicators can respond to short-term fluctuations or local events, increasing the reliability of the assessment is achieved by combining them and analyzing the dynamics over time.

Within the framework of the proposed approach, it is advisable to use the following principles:

1. The principle of multiple confirmations. The assessment of increased financial stress is based on a set of agreed signals, and not on a single indicator. For example, increased volatility combined with changes in investor behavior and increased market synchrony.

2. The principle of hierarchical significance. Signals of different levels have different diagnostic weight: primary symptoms act as early warnings, systemic signals indicate the spread of tension, and crisis signals indicate a transition to a high phase of instability.

3. The principle of consistency. The reliability of interpretation increases when signals occur in a logical sequence – from primary symptoms to systemic and crisis manifestations. Such dynamics reflect a gradual escalation of risks.

Table 1

Hierarchical structure of market signals of financial stress

Signal level	Characteristics of the market condition	Main symptoms	Typical indicators	Interpretation
Level 1. Primary market symptoms	Initial signs of changing market environment and increasing uncertainty	Increasing volatility, increased trading activity, local fluctuations	Volatility of returns, trading volumes, short-term dynamics of indices	Indicate changing investor expectations and possible accumulation of imbalances
Level 2. Systemic signals	Spread of financial stress across market segments	Synchronization of asset movements, increasing correlations, capital flows into protective assets	Correlations between markets, gold dynamics, currency indices	Indicate the formation of systemic risk and increased market vulnerability
Level 3. Crisis signals	Phase of high instability and turbulence	Massive sales of risky assets, sharp increase in volatility, liquidity shortage	VIX index, falling stock indices, sharp changes in government bond yields	Indicate the transition of the market to a crisis state

Source: created by the author

4. The principle of signal stability. For practical monitoring, signals that are repeated or persist for a certain period are considered more significant, while single spikes may be the result of short-term market fluctuations.

These principles form the methodological basis for using a hierarchical system of signals as an early warning tool aimed at identifying periods of increased financial stress.

The proposed system allows interpreting the state of the financial market within three main regimes: stability, stress and crisis, which corresponds to the logic of the development of financial imbalances.

The stability regime is characterized by the absence or single appearance of primary symptoms, while systemic and crisis signals are not observed.

The stress regime is recorded in the case of regular appearance of primary symptoms in combination with systemic signals, which indicates the spread of risks between different segments of the financial market.

The crisis regime corresponds to the phase when, against the background of already formed systemic instability, crisis signals appear, reflecting the materialization of risks and a sharp increase in market turbulence.

Conclusions. The study substantiates the feasibility of using approaches to early diagnosis of financial crises as a tool for reducing macroeconomic risks and increasing the stability of financial systems. The concept of a hierarchical system of market signals is proposed, which involves dividing financial instability indicators into three levels: primary symptoms, systemic signals and crisis signals. Such a structure allows interpreting the process of financial stress accumulation as a sequential transition between the regimes «stability → stress → crisis».

The advantage of the proposed approach is its interpretability and practical orientation. The hierarchical system of market signals allows systematizing market indicators and using them for regular monitoring of financial stability without the use of complex econometric models. This expands the possibilities of macroprudential analysis, assessment of market risks and making investment decisions in periods of increased uncertainty.

At the same time, the proposed system has certain limitations, in particular, the sensitivity of individual indicators to short-term fluctuations and the dependence of the assessment results on the composition of the indicators used. Therefore, its practical application should be combined with the analysis of signal combinations and their time dynamics.

Further research may be aimed at clarifying the composition of indicators for different segments of the financial market and developing methods for their aggregation into an integral indicator of financial stress.

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