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THE CONCEPT OF DATA COMPLEMENTARITY IN FINANCIAL MARKETS

The article is devoted to the study of methodological approaches to financial market analysis, considering the fragmentation and incompleteness of financial data sets. The necessity of integrating alternative data sources to enhance the accuracy of analytical assessments is substantiated. The primary methods for researching financial markets – quantitative, qualitative, and mixed – are summarized, with their advantages and limitations highlighted. The concept of financial data complementarity is introduced, advocating the use of complementary datasets to address informational gaps. A multi-step methodology for assessing complementarity is developed, including data normalization, correlation analysis, parametric and non-parametric tests, and regression analysis.

Keywords: *financial markets; complementarity; data sets; data research methods; Adaptive Market Hypothesis; Efficient Market Hypothesis; forecasting.*

Fig. 1. Tabl. 2. Lit. 10.

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КОНЦЕПЦІЯ КОМПЛІМЕНТАРНОСТІ ДАНИХ НА ФІНАНСОВИХ РИНКАХ

Стаття присвячена дослідженню методологічних підходів до аналізу фінансових ринків з урахуванням проблеми фрагментарності та неповноти масивів фінансових даних. Обґрунтовано необхідність інтеграції альтернативних джерел даних для підвищення точності аналітичних оцінок. Узагальнено основні методи дослідження фінансових ринків, які поділяються на кількісні, якісні та змішані, а також висвітлено їхні переваги та обмеження. Запропоновано концепцію компліментарності фінансових даних, що передбачає використання взаємодоповнюваних масивів для усунення інформаційних прогалин. Розроблено багатокрокову методику оцінки компліментарності, яка включає нормалізацію даних, кореляційний аналіз, параметричні та непараметричні тести, а також регресійний аналіз.

Ключові слова: *фінансові ринки; компліментарність; масиви даних; методи дослідження даних; гіпотеза адаптивного ринку; гіпотеза ефективного ринку; прогнозування.*

Problem Statement. Financial markets operate in a dynamic environment where information is constantly changing; therefore, the methods used for its assessment and analysis are also evolving. Traditional quantitative research methods, particularly statistical analysis and econometric modeling, often rely on the assumption of completeness, integrity, and representativeness of financial data sets. However, in the real conditions of financial market functioning, one frequently encounters problems such as fragmentation, absence, or distortion of data, which can lead to biased analysis results, erroneous conclusions, and the inability to make accurate decisions.

To overcome these limitations, it is advisable to apply the concept of complementarity of financial data, which involves using complementary data sets to enhance the accuracy and reliability of analytical assessments. The methodological founda-

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tions for identifying and assessing the complementarity of financial data have not been sufficiently explored in the scientific literature, which necessitates the development of an appropriate conceptual approach. Therefore, developing a methodological approach to identifying, evaluating, and utilizing complementary financial data sets to improve the quality of financial market analysis is an urgent issue.

Analysis of Recent Research and Publications. Traditional approaches to the analysis of financial markets are based on the Efficient Market Hypothesis (Fama, 1965) [1], which assumes that all available information is instantly reflected in asset prices, making the market unpredictable. However, numerous empirical studies (Shiller, 2003 [2]; Lo, 2004 [3]) have proven that investors do not always act rationally and that the market is an adaptive system that responds to changes in the information structure and the behavior of participants. In this context, the Adaptive Market Hypothesis developed by A. Lo [3] offers a more flexible approach, according to which market efficiency changes depending on conditions. Studies by E. Peters (1994) [4], F. Black (1986) [5], and W. De Bondt & R. Thaler (1985) [6] confirm that financial markets exhibit signs of fractality, information asymmetry, and overreaction to events, necessitating the use of new methodological approaches to data analysis.

Modern scientific works (Plastun et al., 2023 [6]; Caporale, 2019 [7]) emphasize the importance of integrating various sources of information to improve the quality of forecasting financial processes. However, the scientific literature does not sufficiently address the issue of identifying the complementarity of financial data and its impact on analytical results.

The purpose of this article is to develop a conceptual approach to assessing and using the complementarity of financial data in financial markets.

Presentation of the Main Research Material. The pragmatics of using scientific and methodological approaches in real conditions of financial market development lie in testing and determining the validity (adequacy, justification) of relevant methods for studying specific financial phenomena and processes using data sets that characterize their course and transformation over time (Table 1).

Typically, quantitative research methods are used to assess the transformation of financial markets. However, alongside these methods, other qualitative research approaches are also employed in the study of financial indicators. Qualitative research methods in the financial sphere require a clear formulation of research questions and problems. The use of mixed methods (a combination of quantitative and qualitative methods) has a synergistic effect, or in other words, the triangulation of methods, which broadens the possibilities of studying the transformation of financial markets. N. Devasiri, Y. Weerakun, and A. Aziz [8] argue that financial research based on quantitative methods and proxy variables derived from statistical models may fail to account for the contextual features of financial markets.

The authors emphasize that the combination of quantitative and qualitative methods (triangulation) contributes to a deeper understanding of the dynamics of financial markets, particularly their transformation under the influence of macroeconomic and behavioral factors. Mixed methods allow for a more comprehensive understanding of the phenomena being studied, as quantitative methods provide statistical validity of the results, while qualitative methods reveal the underlying causes and motives behind changes. This is especially relevant in financial research, as mar-

kets are complex adaptive systems influenced by both objective economic indicators and subjective expectations of participants. Scholars also emphasize that combining quantitative and qualitative methods can enhance the validity, completeness, and confirmation of results while minimizing the shortcomings inherent in using only one method.

Table 1. **Methods of researching data in financial markets,** *improved by the author, taking into account [8]*

Method	Description		Advantages
Quantitative	Descriptive	Quantitative analysis is designed to describe the characteristics of variables (indicators, indicators)	Research into the current state, trends, relationships, comparisons, forecasting of quantitative financial indicators
	Comparative	Comparative analysis of one or more independent variables with a dependent variable	
	Related to the relationship	Analysis of the relationship and its nature between independent variables (indicators)	
	Historical	Forecasting financial data based on past financial trends	
	Alternative	Methods based on the use of implicit indicators or available data, which allow, use appropriate economic and mathematical transformations, to analyze trends in financial markets. For example, the nowcast method is a method of using alternative data to forecast financial and economic indicators in the short term.	Obtaining operational forecast values of financial indicators through the use of implicit (proxy) variables
		Data complementarity method – a method that can be used when different data sources describe the same process (phenomenon) in financial markets and can be combined into a single financial data set to eliminate data fragmentation.	Research into interchangeable financial data, which allows the merging and replacement of fragmented data from different sources into a single data set
Quality	Methods used when there is no quantitative data on a financial phenomenon (process) in the past or it is impossible to formalize a financial problem in quantitative terms		Research into individual financial problems that are not quantifiable
Mixed	Simultaneous use of quantitative and qualitative methods in financial market research		Combining the advantages of quantitative and qualitative methods of researching financial data

Therefore, the quality of research into the transformation processes in financial markets, for their identification, assessment, analysis, and timely decision-making,

depends on the availability of the most complete and reliable information (data sets) and the ability to process it using various research methods. Over the past decades, quantitative methods of financial market research, which are based on the formation, evaluation, and analysis of financial data sets derived from the observation of numerous financial indicators, have become the most popular. Quantitative research methods involve the creation of data sets that are formalized in numerical terms and reflect the processes and phenomena occurring in financial markets. However, problems may arise during the formation of quantitative financial data sets, such as the absence of data for a certain period, the lack of data altogether (no historical data), data loss, fragmentation, incompleteness, distortion, or the impossibility of obtaining data.

Before proposing a conceptual approach that will help eliminate data fragmentation by identifying complementary financial data sets, we will first characterize the main methods used in financial market research. In this regard, the methods and approaches to assessing and forecasting financial markets have undergone significant transformation.

Classical methods of analyzing and assessing financial markets, such as the optimal investment portfolio model by G. Markowitz, W. Sharpe's SARM model, and the Black-Scholes option pricing model, are based on L. Bachelier's assumption that the characteristics of financial assets are random variables distributed according to a normal distribution. The theoretical foundation that embodies this postulate is the Efficient Market Hypothesis proposed by Y. Fama, the essence of which is that all significant information is immediately and fully reflected in asset prices, making them practically unpredictable. Their dynamics are described by the «random walk» model.

Y. Fama [1] identified the possible forms of efficiency in financial markets:

Weak form – asset prices reflect all past information (historical prices, trading volumes, etc.), meaning technical analysis does not provide any advantages;

Semi-strong form – prices take into account not only past data but also all publicly available information (company reports, macroeconomic data, etc.), meaning fundamental analysis does not provide any advantages;

Strong form – the market takes into account even private (insider) information, meaning no investor can gain an advantage, even with exclusive knowledge.

However, despite the popularity of the Efficient Market Hypothesis, practical experience in the functioning of financial markets shows that the assumption of the complete absence of information asymmetry and the rationality of economic agents does not always correspond to reality [9, p. 9].

When it became clear that classical approaches to understanding the principles of development and transformation of financial markets were unable to explain the crisis phenomena and anomalies that arise in them, alternative concepts and theories emerged to explain the behavior of financial markets. The most famous are the theory of behavioral finance (Shiller, 2003) [2], the adaptive market hypothesis (Lo, 2004) [3], the fractal market hypothesis (Peters, 1994) [4], the noisy market hypothesis (Black, 1986) [5], the overreaction hypothesis (De Bondt and Thaler, 1985) [6], and many others. These theories contradict each other, are based on different assumptions and methodologies of analysis, and typically focus on specific aspects of financial markets [10]. A. Lo (2004) [4] attempted to unify them into a single concept, explaining the existing differences by the instability of financial markets.

The Adaptive Market Hypothesis (AMH), proposed by Andrew Lo in 2004, is an alternative approach to the analysis of financial markets that combines the ideas of the efficient market and behavioral economics. It views the market as a dynamic system that changes depending on conditions and adapts to the actions of investors.

Key provisions of the Adaptive Market Hypothesis [4]:

1. Market efficiency changes over time – it depends on competition, technology, the level of information availability, and the behavior of participants.

2. Investors are only partially rational – they use both logical and emotional decisions in their behavior.

3. Financial markets operate on the principles of evolution – strategies that are most effective at a given point in time survive.

4. Financial behavior is adaptive – during crises, investors become more sensitive to risks, and during market growth, they become less cautious.

The main differences between the Efficient and Adaptive Market Hypotheses are presented in Table 2.

Table 2. **Key differences between EMH and AMH,** *improved by the author*

Description	Efficient market hypothesis	Efficient market hypothesis
The nature of the market	Static, always effective	Dynamic, adaptive
Rationality of investors	Complete rationality	Bounded rationality
Possibility of stable profit	Impossible (without taking additional risk)	Possible in the short term
Market transformation	None (closed process)	Constant development, changing strategies

Thus, the practical significance of the Adaptive Market Hypothesis (AMH) lies in explaining the existence of financial crises, panics, and market inefficiencies; helping investors flexibly change strategies in response to market conditions; and developing algorithmic trading methods that account for the variability of market efficiency.

In this regard, the AMH recognizes that market efficiency varies depending on the information environment. Therefore, the completeness and quality of data sets significantly affect the accuracy of the analysis. This makes the concept of complementarity an essential element of modern financial research, as combining data from different sources can enhance the reliability of estimates and forecasts. In other words, the complementarity of financial data aligns with the adaptive nature of the market and enables a flexible response to changes in the information environment.

In this context, the study of the transformation of financial markets can be viewed through the lens of the main properties and characteristics of the data that describe their functioning. The primary properties of data in financial markets include volatility, liquidity, profitability, risk, and fractality. Among the key characteristics of data in financial markets, we highlight stationarity, asymmetry, noise, extremity, and reactivity, among others. We propose adding the characteristic of complementarity to the main characteristics of financial data sets.

By «complementarity» of data in financial markets, we mean the property of financial data sets that share a common nature, similar properties, have a high level of correlation, and are statistically indistinguishable from one another. This ensures

that the elements of these data sets can mutually complement or replace each other.

Determining the complementarity of data in financial markets is complex, and no established methodology currently exists to address this issue. As a result, we have developed an original multi-step mechanism for assessing the complementarity of data sets, which includes the following stages (Fig. 1):

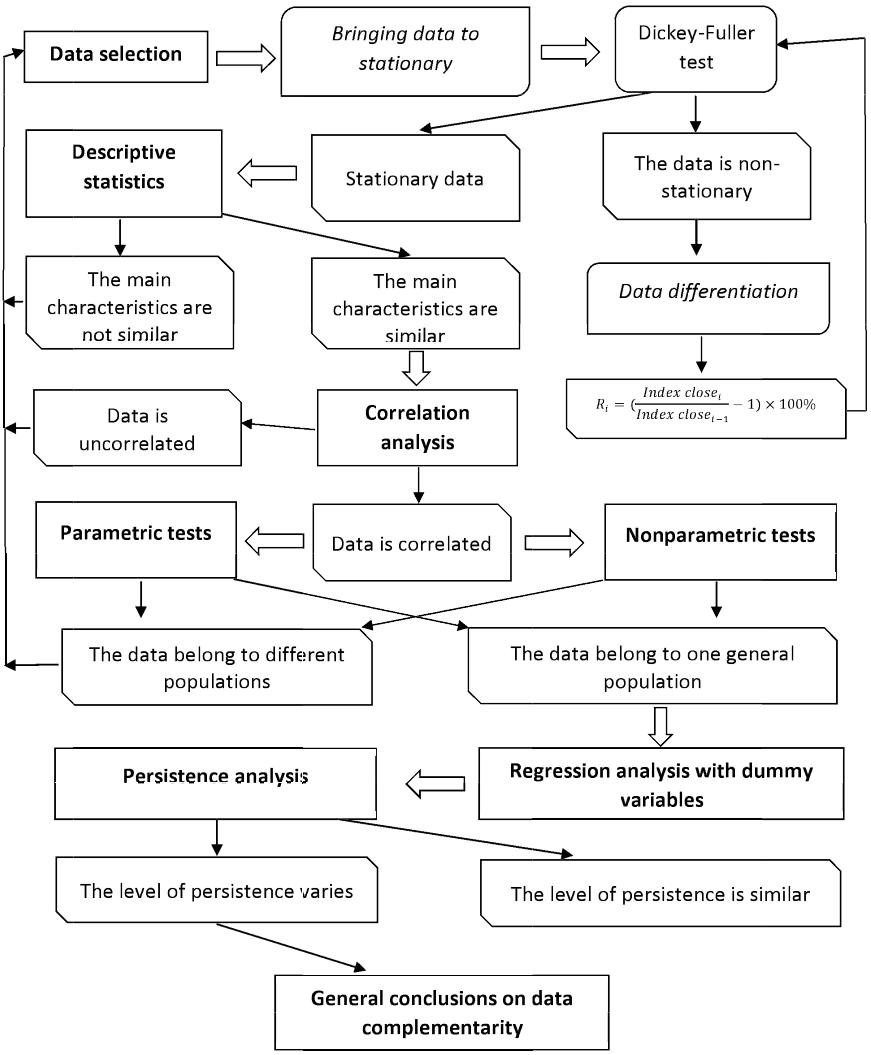

Fig. 1. **Algorithm for implementing a conceptual approach to assessing the complementarity of financial data,** *proposed by the author*

1. Normalization and reduction of data to stationary form;
2. Calculation of descriptive statistics to assess the correspondence of key quantitative characteristics of data sets being checked for complementarity;
3. Correlation analysis to quantify the level of data correlation;

4. Use of parametric tests to identify statistically significant differences between the analyzed data sets;

5. Use of nonparametric tests to identify statistically significant differences between the analyzed data sets;

6. Use of regression analysis with dummy variables as an additional method to check for statistically significant differences between the data sets;

7. Conduct persistence analysis to determine the internal structure of the data and draw conclusions about the similarity of the data sets.

It should be noted that individual elements of the proposed mechanism have been previously tested by other authors (in particular, Plastun et al., 2023) [6] and have proven to be fundamentally effective.

To assess data complementarity, this paper has developed a methodology that involves a multi-stage process for checking data sets, including normalization, analysis of key data characteristics, assessment of the correlation level between the data sets, the use of parametric (t-tests, ANOVA analysis) and non-parametric (Mann-Whitney, Kruskal-Wallis tests) tests to identify statistically significant differences, persistence analysis (using the R/S method), and regression analysis with dummy variables. This comprehensive approach allows us to conclude the level of complementarity of the data sets. The proposed scientific and methodological approach to assessing data complementarity in financial markets is universal and can be applied to other data sets as well.

Conclusions. Summing up the results of the study, we note that the concept of «data complementarity», as proposed in this work, refers to data sets that share a common nature, similar properties, exhibit a high level of correlation, and are statistically indistinguishable from one another. This ensures that the elements of such data sets can mutually complement or replace each other. Data complementarity is an essential characteristic of financial data, offering fundamentally new opportunities for utilizing data separated in time. This is particularly relevant when gaps exist in a specific data set on financial markets (for instance, when one data set begins later or ends earlier than another). According to the proposed concept of data complementarity, elements of one data set can replace corresponding elements of another, thereby forming a more complete data set while maintaining its essential properties.

The complementarity of financial data is critical for qualitative analysis of financial markets. The main practical applications of this concept are as follows:

Eliminating data gaps: In cases where historical data is missing or data sets are fragmented, the use of complementary sources of information helps reduce errors in calculations and provides a more comprehensive view of market dynamics;

Increasing forecasting accuracy: The methodology for assessing complementarity helps create more representative samples for modeling. This is particularly valuable in areas such as risk management, algorithmic trading, and macroeconomic forecasting;

Reducing the impact of information anomalies: Complementarity helps smooth the effect of random events and information noise, leading to more stable financial analysis;

Optimizing investment strategies: The ability to eliminate data fragmentation enhances forecasting accuracy, aiding in more effective asset allocation and the adaptation of investment decisions to changing market conditions.

In conclusion, the proposed approach to assessing data complementarity in financial markets expands the capabilities of financial research, reduces risks, and increases the accuracy of analytical assessments in an unstable information environment.

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