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ТЕЗИ ДОПОВІДЕЙ

VII Міжнародної науково-практичної конференції «Інформаційні технології в освіті, науці і техніці» (ІТОНТ-2024)

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Тези доповідей VII Міжнародної науково-практичної конференції «Інформаційні технології в освіті, науці і техніці» (ІТОНТ-2024), (Черкаси, 23-24 травня 2024 р.) [Електронний ресурс]. Черкаси : ЧДТУ, 2024. 349 с.

Матеріали конференції висвітлюють основні напрями розвитку інформаційних технологій і систем та їх використання в освіті, науці, техніці, економіці, управлінні, медицині.

У матеріалах розглядаються питання, пов'язані з комп'ютерним моделюванням фізичних, хімічних і економічних процесів, інформаційною безпекою та застосуванням інформаційно-комунікаційних технологій у техніці, наукових дослідженнях і управлінні складними системами, з використанням інформаційно-комунікаційних технологій в освіті, зі створенням, впровадженням і використанням науково-освітніх ресурсів у закладах вищої освіти, а також з проблемами підготовки ІТ-фахівців у вищій школі.

Для наукових і педагогічних працівників, аспірантів і студентів закладів вищої освіти.

Публікується згідно з рішенням Вченої ради Черкаського державного технологічного університету від 20.05.2024 р., протокол № 9.

Матеріали подані в авторській редакції. Автори опублікованих матеріалів несуть повну відповідальність за підбір, точність наведених фактів, цитат, даних, власних імен, посилань, грамотність, літературний стиль та інші відомості. Редколегія залишає за собою право скорочувати та редагувати подані матеріали. Рукописи не повертаються. Організатори конференції та члени редколегії не завжди поділяють думки авторів.

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КОРОТКИЙ ЗМІСТ

BRIEF CONTENTS

THE STATES OF IRREVERSIBILITY IN THE ENERGY-RELATED MARKETS AND THEIR IDENTIFICATION

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Abstract. The energy sector plays a crucial role in a nation's economic development by addressing imbalances between production and consumption of energy resources. Numerous factors can influence the prices of oil, and fluctuations in one commodity can trigger short-term, medium-term, or long-term fluctuations in another. Interconnectedness among the commodities of the energy sector forms a highly complex, multi-parametric system characterized by simultaneously operating trends that are both contrary to previous dynamics and more predictable periods. Regimes of unpredictability exemplify the irreversibility of the studied system, and a loss of irreversibility may indicate destructive processes. Consequently, this study presents indicators-precursors of crisis events, characterized by a decrease in irreversibility as they occur. Using the example of daily West Texas Intermediate (WTI) spot prices (US$/BBL) from January 2, 1986 to March 18, 2024, we provide an indicator that precedes crisis states in the oil market. The construction of such an indicator is based on the algorithm of permutation patterns. This study demonstrates that the irreversibility of the system can serve as a precursor to financial crises.

Keywords: irreversibility, oil market, complex systems, indicator-precursor.

Presentation of the main material. The development of the global economy is inextricably linked to the strategic resources of the crude oil markets [1]. A prevailing view holds that marginal fluctuations in energy commodity prices can stimulate global economic growth. However, drastic fluctuations in these prices necessitate that both importing and exporting nations promptly identify and address emerging issues through appropriate economic adjustments. Moreover, the sustainable development of the global economy is contingent upon the dynamics of energy-related markets. Accurate forecasting of oil prices is of paramount importance to financial institutions and private companies, as their fluctuations are a key variable in assessing risk and forecasting macroeconomic indicators.

The goal of this study is to measure the degree of irreversibility in oil market and present a perspective on using complex systems theory to develop robust and powerful indicators or indicators-precursors of possible market risks. Our research considers the West Texas Intermediate (WTI) crude oil spot price over the period from January 2, 1986 to March 18, 2024.

Time series irreversibility measure based on permutation patterns. The concept of analyzing permutation patterns (PP) was initially proposed by Bandt and Pompe [2] to provide researchers with a simple and efficient tool to characterize the complexity of dynamics in real-world systems. In contrast to other approaches, such as entropies, fractal dimensions, or Lyapunov exponents, the PP method circumvents amplitude thresholds and operates on ordinal PP rather than causal values inherent in time series dynamics. The frequencies of these patterns enable the distinction between deterministic processes and completely random ones.

The calculations of PP assume that the time series $X = \{x(i) \mid i = 1, \dots, N\}$ is partitioned in overlapping subvectors $\vec{X}(i) = \{x(i), x(i+\tau), \dots, x(i+[d_E-1]\tau)\}$, where d_E is the length of corresponding vectors (number of elements to be compared) and τ is the embedding delay that controls time separation between elements.

After the embedding procedure, each subvector is mapped to an ordinal PP

$$\pi = \{r_0, r_1, \dots, r_{d_E-1}\} \text{ of } \{0, 1, \dots, d_E - 1\},$$

which has to fulfill the condition

$$x(i + r_0) \leq x(i + r_1) \leq \cdots \leq x(i + r_{d_E - 1}).$$

A compelling measure of time irreversibility based on PP can be derived by considering the relative frequencies of permutation patterns for both the initial and time-reversed series. Correspondingly, if both cases exhibit approximately equivalent probability distributions of their patterns, the time series is deemed reversible. Conversely, divergent probability distributions would indicate an irreversible time series.

For the permutation-based indicator, we will utilize the probability density functions (PDFs) of permutation patterns (PP). If our system is time-reversible, we hypothesize that the probability distributions of forward and backward time characteristics should be identical. For irreversible processes, we anticipate finding statistical non-equivalence. In accordance with [3], this deviation will be quantified through the Jensen-Shannon distance metric:

$$JS = \sqrt{[D_{KL}(p \,||\, m) + D_{KL}(q \,||\, m)]/2}, \quad (1)$$

where p corresponds to a distribution of the *retarded* characteristics and q to the distribution of the *advanced* characteristics, $m = (p + q)/2$, and $D_{KL}(\cdot)$ is the Kullback-Leibler divergence [4].

Results. Further, for measuring the degree of irreversibility in the oil market, we present the comparative dynamics of the presented indicators calculated with the usage of the sliding window approach [5-7] along with the studied series. We have tested different values of embedding dimension and time delay for permutation-based irreversibility and found that $d_E = 3$ and $\tau = 15$ gave the most adequate results.

Fig. 1 presents JS measure of PP calculated for the initial time series of WTI crude oil spot prices.

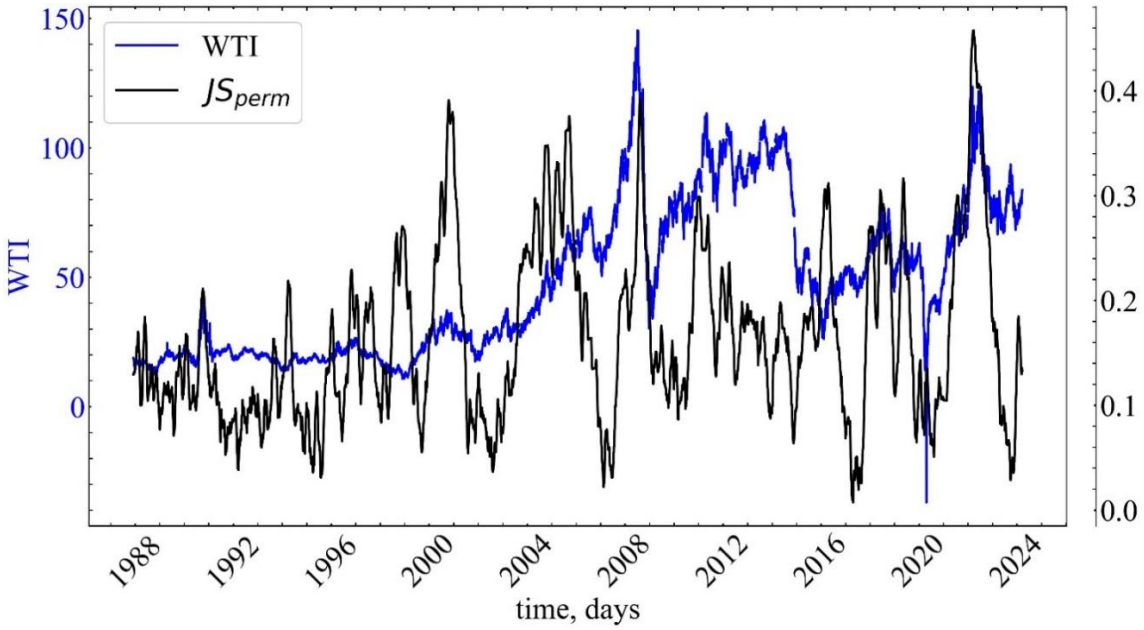

Fig. 1. The JS measure of irreversibility based on PP calculated for the WTI crude oil spot prices

Fig. 1 illustrates that irreversibility exhibits an increasing trend during the transition to crash events, indicating an escalation of nonlinearity in these regions. This observation suggests that prior to the crash period, the formation of permutation patterns becomes increasingly asymmetrical, which is indicative of an augmentation in the irreversibility indicator.

Conclusions. This study explored the application of irreversibility theory and measure on its basis that used permutation patterns. The sliding window algorithm was utilized to construct suitable indicator for monitoring variations in the dynamics of the oil market. An analysis was performed on the time series of West Texas Intermediate spot prices to investigate how

irreversibility (asymmetry) manifests itself in energy-related markets. The study demonstrated that crashes of the oil market are non-equilibrium events that can be characterized as chaotic dissipative processes with long-range correlations and nonlinear stochastic dynamics.

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References

1. Vandyck T. Wójtowicz K. Economic exposure to oil price shocks and the fragility of Oil-Exporting countries / T. Vandyck, A. Kitous, B. Saveyn, K. Keramidas, L.R.L. Santos // Energies, 2018. №11(4). P. 827. https://doi.org/10.3390/en11040827
2. Bandt C. Permutation entropy: a natural complexity measure for time series / C. Bandt, B. Pompe // *Phys. Rev. Lett.*, 2002. №88. P. 174102. https://doi.org/10.1103/PhysRevLett.88.174102
3. Grosse I. Analysis of symbolic sequences using the Jensen-Shannon divergence / I. Grosse, P. Bernaola-Galván, P. Carpena, R. Román-Roldán, J. Oliver, H.E. Stanley // Phys. Rev. E., 2002. №65(4 Pt 1). P. 041905. https://doi.org/10.1103/PhysRevE.65.041905
4. Lacasa L. Time series irreversibility: a visibility graph approach / L. Lacasa, A. Nuñez, É. Roldán // Eur. Phys. J. B, 2012. №85. P. 217. https://doi.org/10.1140/epjb/e2012-20809-8
5. Bielinskyi A. Econophysics of cryptocurrency crashes: a systematic review / A.O. Bielinskyi, O.A. Serdyuk, S.O. Semerikov, V.N. Soloviev // Machine Learning for Prediction of Emergent Economy Dynamics, 2021. vol. 3048. ISSN 1613-0073. p. 31-133.
6. Bielinskyi A. Irreversibility of financial time series: a case of crisis / A.O. Bielinskyi, S.V. Hushko, A.V. Matviychuk, O.A. Serdyuk, S.O. Semerikov, V.N. Soloviev // Machine Learning for Prediction of Emergent Economy Dynamics, 2021. vol. 3048. ISSN 1613-0073. p. 134-150.
7. Bielinskyi, A., Soloviev, V., Solovieva, V., Matviychuk, A., Hushko, S., Velykoivanenko, H. (2023). Stock Market Crashes as Phase Transitions. In: Antoniou, G., *et al.* Information and Communication Technologies in Education, Research, and Industrial Applications. ICTERI 2023. Communications in Computer and Information Science, vol 1980. Springer, Cham. https://doi.org/10.1007/978-3-031-48325-7_15

EVALUATION OF THE ECONOMIC EFFICIENCY OF INFORMATION AND COMMUNICATION TECHNOLOGIES IN THE INTENSIFICATION OF THE DEVELOPMENT OF THE AGRICULTURAL SECTOR IN AZERBAIJAN

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Abstract. Development problems of the agrarian sector, increasing productivity, and creating stable of important food products have been placed at the basis of the economic policy of every state. Accelerating the development of the agricultural sector in Azerbaijan and using the available opportunities are important conditions. Effectiveness of these processes, identification of the causes of the considered problems and taking of necessary measures should be consistent and include the requirements and approaches of the modern era. For this, the transparency of information and technology exchange, the expansion of the use of ICT opportunities in various fields of society and economy, including the agricultural field, should be determined, and the factors that determine the increase of its efficiency should be considered, substantiated should be implemented.

The study reflects the preparation of scientific and practical proposals for the systematization, disclosure and determination of solutions to modern problems related to increasing the economic efficiency of ICT in the agricultural sector, which is of great importance in the structure of the national economy in Azerbaijan, and the preparation and application of mechanisms in accordance with the progressive world experience. Therefore, the scientific results and practical suggestions made in the research can be used in the modeling of the development of the agricultural sector, in the development of practical mechanisms, in the