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Modeling of investment attractiveness of countries using entropy analysis of regional stock markets

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ABSTRACT

The current study focuses on the problem of determining investment attractiveness of countries by means of monitoring regional stock markets. The method of using the permutation entropy as a model of investment attractiveness estimation is suggested. The permutation entropy for the time series of stock markets of countries for the period from 2005 to 2018 is calculated. The countries with high, middle or low income in Europe, Central Asia, East Asia, the Pacific, and North America were selected for the study. The article presents the results of modelling and analysis of dynamic properties of regional stock markets using the permutation entropy. The behavior of the permutation entropy and stock markets is analyzed and conclusions about the possibility of rapid monitoring of the investment attractiveness of countries by classifying the states of the stock markets of these countries are drawn. Particular attention is paid to crisis periods. It has been shown that the permutation entropy rapidly decreases in a universal way in the pre-crisis period, which can serve as an indicator of the precursor for crisis phenomena. Determining the pre-crisis, actual crisis and post-crisis periods will allow the investor to make the right decision on time. The advantages of using the permutation entropy method as a tool for high-frequency monitoring of stock markets and modelling the investment attractiveness of countries are pointed out. The results of determining investment attractiveness in terms of the permutation entropy and ratings of the world countries, compiled by the world-wide rating agencies and literature, are compared.

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INTRODUCTION

In the context of the world global crises, the lack of available funds leads to increasing the competition in financial markets, increases the requirements for investors. The lack of awareness about the investment objects at both micro and macro levels, often becomes a barrier to the development of investment activity. Investment attraction involves justification and selection of investment priorities using transparent and clear tool set for investors. The concept of investment attractiveness can be interpreted from the point of view of both investors and recipients. In this paper, the investment attractiveness is considered to be a complex of objective features that allow timely accepting (or support) the decision about investing to achieve a specific goal. To create a single information space, the methods of fundamental analysis reflected in various ratings are traditionally used; they allow the participants of investment process to determine both the investment object and the source of raising funds. The most well-known and reputable international agencies and journals in the world are the following:

Moody's Investors Service, Standard and Poors Rating Services, Fitch Ratings, Transparency International, Euromoney, Economic Intelligence Union, and others. For rating purposes, they all use a variety of their own methods to assess investment attractiveness. According to (Euromoney, 2018) conducting (twice a year) a comprehensive assessment of the investment attractiveness of the countries in the world based on 9 groups of indicators using the crowd sourcing approach to measure the country's investment risk and reliability of countries, in the third quarter of 2018, Canada has the lowest risk (10th place) among the studied countries. The following countries are positioned as follows: Germany (11th), the United States (16th), the United Kingdom (20th place), France (21st place), Japan (26th place), China (42st place), Ukraine (128th place). According to the World Economic Forum's (2018) Global Competitiveness Rating, countries are positioned as follows: the United States (2nd), Germany (5th), Hong Kong (6th place), the United Kingdom (8th place), Japan (9th place), Canada (14th place), France (22th place), South Korea (26th place), China (27th place), Ukraine (81st place). UNCTAD (2018) suggests using the index of the actual state of importing investments and potential index of importing investments to assess the investment attractiveness of the country. Heritage Foundation, (2018) offer a methodology for assessing the investment attractiveness based on the global indices of economic freedom. According to this indicator, there is the following rating position of the countries: Hong Kong (1st place), the United Kingdom (8th place), Canada (9th place), the United States (18th), Germany (25th), South Korea (27th), Japan (30th place), France (71st place), China (110th place), Ukraine (150th place). However, it should be noted that mainly, ratings, firstly, have rather narrow nature, and secondly, based entirely on statistical data (formed with a delay) or according to experts. The analysis of scientific works shows that a widely accepted method of modelling investment attractiveness is econometric - the construction of a multi-factor regression model. Econometric models were used: to study the relationship between international trade flows and direct foreign investment (Anwar and Nguyen, 2010; Bekhet and Othman, 2011; Karray and Driss, 2009) to analyze the investment climate for Latin American countries (Quazi, 2007); to identify positive effects on foreign direct investment from the developed countries to developing countries (Guerina and Manzocchi, 2008) to identify significant factors for the inflow of direct foreign investment in developing countries (Demirhan and Masca, 2008). Horna *et al*. (2017) also use a multi-factor regression model; and the method of SWOT-analysis is used to determine the factors and conditions for forming the investment attractiveness of Ukraine. Vakulich (2014) offers a factor model for monitoring the investment climate of the country's economy on the example of Ukraine. Kharlamova (2009) proposes macroeconomic models to determine Ukraine's investment potential. Birnleitner (2014) analyzes the impact of macroeconomic factors on enhancing the attractiveness of the country and attracting direct foreign investment, which has determined that investors will benefit from countries with high levels of political stability, tax policy, legislation and cost-effectiveness. Macroeconomic factors as external factors for the formation of investment decisions were considered by McCarthy and Perreault (2002); Porter (2008). Škuflić *et al*. (2013) suggest PROMETHEE, the method of decision making criteria to assess the attractiveness on the example of the countries SEE-6 and EU-27. Saaty (1993) offers a model of an analytic hierarchy, and Nganga and Maruyama (2015), use this model to evaluate the market attractiveness of Sub-

Saharan African countries. Abid and Bahloul (2011) suggested a methodology based on a combination of a gravity model, a model of analytic hierarchy, and a model of targeted programming to determine the attractiveness of the countries of the Middle East, North Africa, and Central Asia. The conclusions about recipient countries being the most attractive for investing and their investor countries are drawn due to the application of this methodology. To analyze the decision of attracting direct foreign investment in the ASEAN countries, the TOPSIS method is used (Karimi *et al*., 2009). In Lörincz (2018) investment attractiveness for recipient countries in Central and Eastern Europe is calculated from the point of view of Western European investor countries. The calculation is based on three factors being a simplified model based on the Global Competitiveness Index and the GSLI methodology (A.T.Kearney, 2016). Androsova *et al*. (2017) offer an integral index of investment attractiveness of countries, which allows choosing the best solutions in a globalizing environment. In addition to the fundamental analysis for the country's investment attractiveness, a technical analysis is used, which, according to Pring (2014), is an investment approach based on the idea that prices move in direction and their direction is determined by changing the attitude of investors under the influence of various forces - economic, political and psychological. In work propose an original approach to determine the investment attractiveness of countries by a method of technical analysis. Stock markets are indicators of investment attractiveness of the countries and have high informative content in relation to the processes taking place in the economies of these countries. However, it should be noted that due to the complexity of these objects, it is very difficult to describe them adequately by some formalized model with sufficient accuracy. Economic systems, like systems of any other nature, generate signals. Therefore, one of the promising approaches to the analysis of stock markets is the study of time series dynamics (Loskutov, 2008). Empirical studies have shown that the scalar time series can restore such dynamic and structural properties of the studied system as to determine the degree of their complexity and chaos nature, to assess stability, to perform pre-predictive analysis, to obtain a time horizon of behavior predictability, relaxation period, etc., using modern interdisciplinary methods for this, such as entropy, recurrent, fractal analysis, Markov chains, and others. (See, e.g., Zunino *et al*., 2009; Soloviev *et al*., 2010; Derbentsev *et al*., 2010; Danylchuk *et al*., 2016; Babenko *et al*., 2018). The purpose of work is to model and define the investment attractiveness of countries by studying the states of regional stock markets using the permutation entropy. This study has been carried out in Ukraine; Cherkasy, Kharkiv, Kyiv in 2018.

MATERIALS AND METHODS

To implement the proposed approach in practice, the time series of daily values of stock market indices (Yahoo Finance, 2018; Invest Funds, 2018) are selected. The time series are divided into the following groups: the countries of North America (the United States, Canada), the countries of Europe and Central Asia (France, Germany, United Kingdom, Ukraine), the countries of East Asia and the Pacific (China, Hong Kong, Japan, South Korea). The length of time series is the same and covers the period from 03-January 2005 to 19-December-2018. The choice of these countries for the study is not accidental, because some events arouse a special interest, e.g., the influence of socio-political and economic events for Great Britain, which initiated disintegration processes, for Germany, which is the flagship of the European economy, for Ukraine, which began the processes of integration into the European Union, etc. Today, the development of the Asian sector is very important for the influence on the world economy. The issue of attracting investments is also significant for these countries.

Permutation entropy

The permutation entropy is an indicator of complexity for chaotic time series or a measure of disorderly (random) information (Bandt and Pompe, 2002). The permutation entropy does not depend on the actual values of the time series, since the method of permutation entropy is based on approaches of symbolic dynamics and uses only relative frequencies of different sequences of symbols. The time series is considered $X = \{x_t: t = 0,1, \dots, N\}$ taking into account all $n!$ possible permutations π that can be formed from different numbers of the time series for a given order n. The order n determines the amount of information contained in each sequence. This vector is associated with an ordinal pattern, which is

defined as a permutation π and satisfies $x_{\pi t} < x_{\pi t+1} < \cdots < x_{\pi t+(n-1)}$. The relative frequency for each permutation π determined, using Eq. 1.

$$p(\pi) = \frac{\#\{t \mid 0 \le t \le T-n, (x_{t+1},\ldots,x_{t+n}) has\ type\ \pi\}}{T-n+1}. \quad (1)$$

For a finite number of values, Eq. 1 is the best way to estimate the permutation frequency. To determine the permutation frequency accurately, provided that the time series is infinite, it is necessary to find the boundary $T \to \infty$ in Eq. 1.

The formula of the permutation entropy of order $n \ge 2$ has the form of Eq. 2.

$$H(n) = -\sum p(\pi) \log p(\pi). \quad (2)$$

Permutation entropy can acquire values within $0 \le H(n) \le \log n!$. The maximum value can be obtained under the condition of an equally probabilistic case (all cases are equal n in the sample) and the minimum value if only one of the $n!$ permutations is implemented in the whole sample (i.e., the values of the system are completely predictable). The value of the permutation entropy $H(n) < \log n!$ indicates a dynamic time series. Taking into account the experimental data obtained, Bandt and Pompe (2002), suggest to divide the value of permutation entropy into *n - 1*, since the comparison begins with the second value, using Eq. 3.

$$h_n = \frac{H(n)}{n-1}. \quad (3)$$

Avilov *et al*. (2013) show that the dependence of permutation entropy on the order can be avoided by introducing the normalized permutation entropy, the values of which range from 0 to 1, according to Eq. 4.

$$H(n) = \frac{-\sum p(\pi) \log p(\pi)}{\log n!}. \quad (4)$$

The order of permutation entropy is an important parameter. Bandt and Pompe (2002) recommend *n* = 3, … , 7 and carry out calculations with *n* = 3, 4, 5 in their work. Bofetta *et al*. (2002) recommend choosing a dimension in the range of 6 to 12 to discrete systems. Makarkin *et al*. (2017) believe that the determination of dimension depends on each particular system. Besides, the entropy of permutations depends on the time delay (lag) *L*, by which the time interval between the patterns is given in Fig. 1.

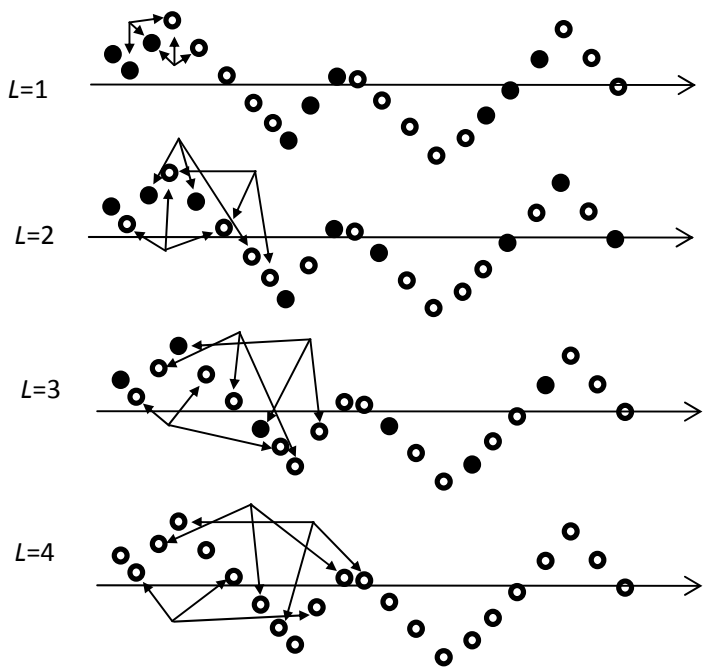

Fig. 1: Signal patterns for different values of time delay (Avilov and Popov, 2014)

RESULTS AND DISCUSSION

Permutation entropy is calculated according to the time series of stock indices using the Matlab software. The parameters for calculating the entropy indicator are: window width – 500 days, step – 5, m = 8, L = 1. The choice of these parameters is confirmed by empirical studies (Danylchuk and Solovyova, 2016). The calculations were made using the moving window procedure. The algorithm for this procedure is the following: a window of a certain width (for example, 500 points in this study) is selected; the value of permutation entropy is calculated in it. Next, the window shifts to a given step (5 points) and re-calculates the value of permutation entropy. These actions continue until the time series runs out. As a result, a time series of permutation entropy values is obtained. The dynamics of the initial series and the permutation entropy are compared with the purpose of identifying the states of stock markets. A characteristic feature of the permutation entropy is a rapid drop in the value of entropy in pre-crisis periods (actual crises are indicated by arrows in Fig. 2). This characteristic behavior of the indicator can be used as a precursor indicator of crisis phenomena. Fig. 2 shows the dynamics of stock indices at the closing price on a relative scale.

In Fig. 2, the arrows show the world global crises of 2008, 2011 and 2015. As can be seen, not all markets have similar trends of behavior in times of global crisis; European stock markets differ in their reaction to certain political events, such as Brexit or the presidential election. However, it is obvious that countries lose their investment attractiveness in times of crisis. Therefore, the problems of monitoring, pre-predicting analysis and timely response to possible crisis phenomena become actual. Figs. 3 to 5 shows the comparative dynamics of output time series and corresponding indices of permutation entropy. For better visualization, the results are presented on a relative scale.

The analysis of Fig. 3 allows concluding that the permutation entropy as an indicator of the crisis phenomena, has timely felt the crises of previous periods in the stock markets of Europe and Central Asia. In addition, it can be can concluded that in the last two years, the state of the French market is rather unstable, which may be caused, for example, by many political events in the country (the administration of President Macron, misunderstandings with trade unions, numerous strikes). It is also not the best time

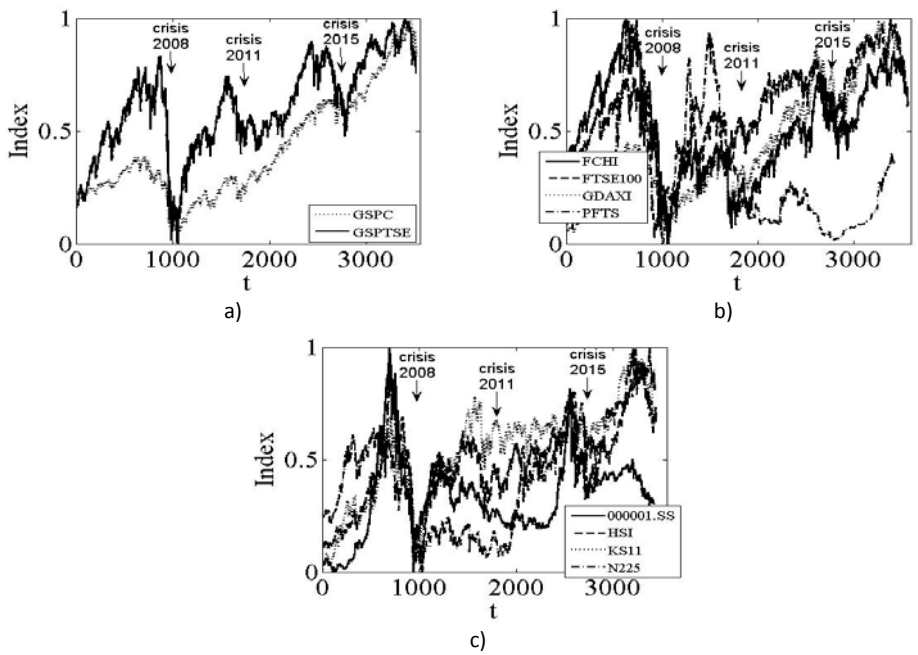

Fig. 2: Dynamics of stock market indices for the countries: (a) the United States, Canada; (b) France, the United Kingdom, Germany and Ukraine; (c) China, Hong Kong, Korea, Japan

for the United Kingdom now that may be the result of Brexit announcement. Despite the growth of the stock market index of Ukraine, according to the permutation entropy, it can be concluded on the adverse conditions for investing in the country. For Germany, it is the period of investment attraction now, because even under the conditions of possible political changes in the course of the country, the state of the stock market

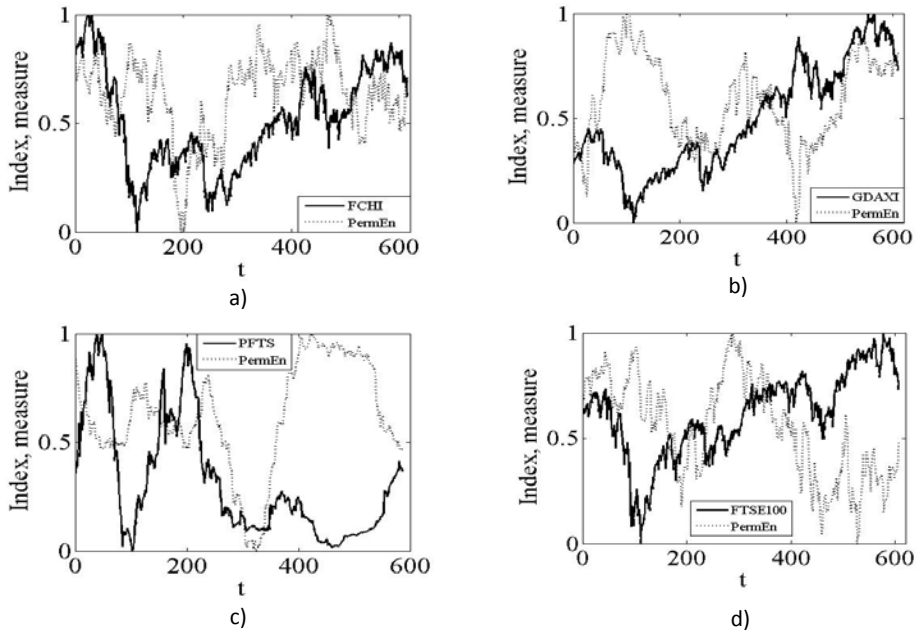

Fig. 3: Comparative dynamics of output series and permutation entropy for stock markets: (a) France, (b) Germany, (c) Ukraine, (d) the United Kingdom

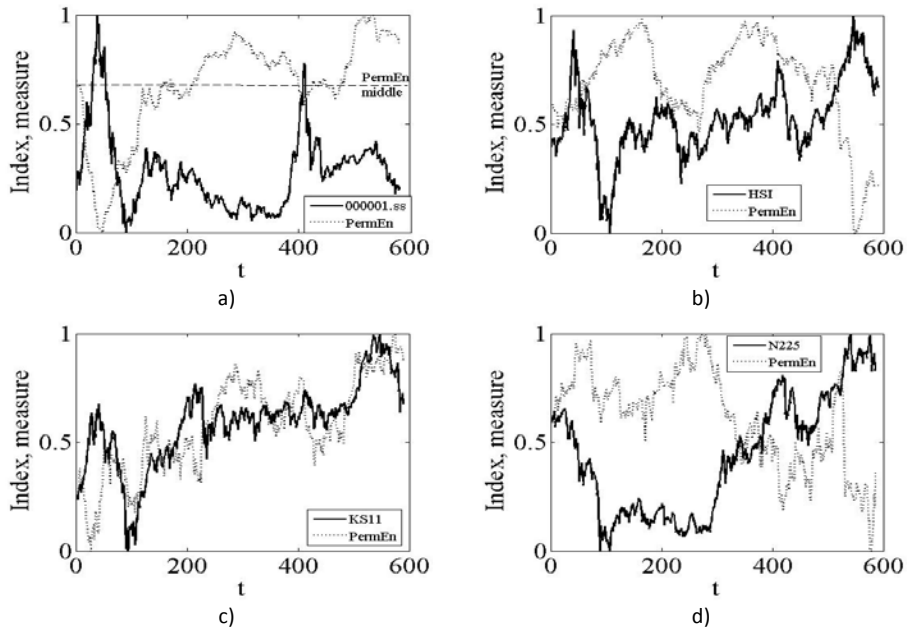

Fig. 4: Comparative dynamics of output series and permutation entropy for stock markets: (a) China, (b) Hong Kong, (c) Korea, (d) Japan

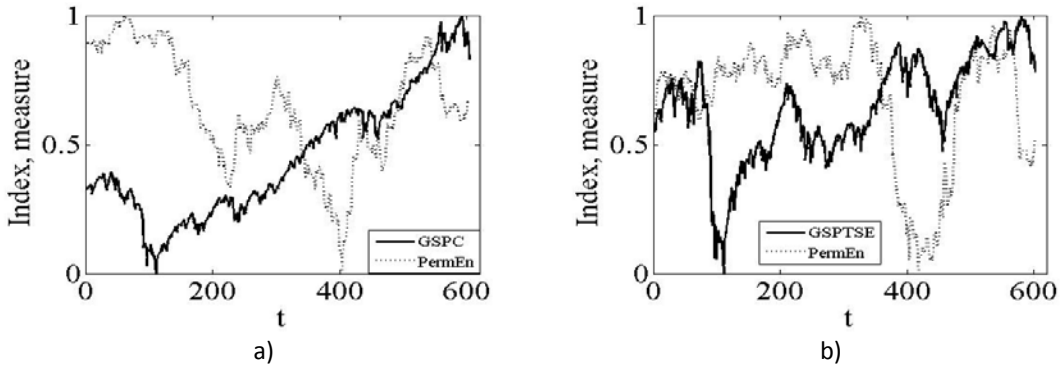

Fig. 5: Comparative dynamics of output series and permutation entropy for stock markets: (a) the United States, (b) Canada

is rather stable. In general, the permutation entropy does not diagnose crisis phenomena for the coming period for all four countries.

Fig. 4 shows the efficiency of the permutation entropy as a precursor indicator of crisis phenomena. The analysis of the current state of stock markets in East Asia and the Pacific makes it possible to draw conclusions about instability for Hong Kong and Japan, and, accordingly, a high risk for investors. China's stock market remains stable, despite the credit crisis. According to the permutation entropy for this group of countries, the investment attractiveness is determined for China and South Korea.

Fig. 5 shows the stock markets of the United States and Canada. The permutation entropy for the United States stock market experienced global crises. The permutation entropy rate starting from the end of 2016 is rapidly falling, signaling unstable state of the market and economy in general. An explanation of this may be the economic and political activities of the administration of President D. Tramp. Despite the fact that the United States economy has always been considered strong, today investors should think about the further coming developments. As for the analysis of Canada stock market, Canada has traditionally been characterized by stability due to its geographical location, the presence of rich natural resources and proximity to the United States market. According to the permutation entropy, Canada felt the crisis in 2008, but emerged from the crisis rather quickly. The crisis of 2011 was also essential for Canada. Since 2017, the permutation entropy index has rapidly decreased, indicating a crisis situation in the Canadian stock market. The explanation for this may consist in, first, restructuring of industry, which obviously leads to certain economic difficulties, and secondly, the situation with the United States, since there is a trade relationship between the US and Canada, the latter depends on the economic and political conditions of the US. The obtained conclusions about the investment attractiveness of the studied countries in terms of the permutation entropy correspond to the above-mentioned ratings (Euromoney, 2018; World Economic Forum, 2018) to some extent, namely, the findings of this study coincide in terms of Germany, South Korea, and Ukraine. However, it should be noted that such a discrepancy may be the result of the fact that these ratings were compiled in the third quarter of 2018 and in September 2017 respectively.

CONCLUSION

In this paper, the investment attractiveness of 10 countries of the world is analyzed using the method of permutation entropy. The permutation entropy is calculated for the time series of the stock market indexes of these countries, as stock markets generally reflect all processes taking place in the countries. Time series are of the same length and cover the historical period from 2005 to 2018. The permutation entropy is the study of the complexity and dynamics of the time series being one of the most effective form and, at the same time, simple in realizing. It is shown that the permutation entropy can be used in real time as a precursor indicator of crisis phenomena, since this indicator reduces its values rapidly in the pre-crisis period that allows identifying the special states of stock markets in a timely manner. Finding general tendencies, negative and undesirable phenomena on the markets will allow investors to make timely decisions. Based on the calculations of the permutation entropy, it is

concluded that the investment attractiveness of such countries as Germany and South Korea is sufficiently high; the low level of investment attractiveness is found for Ukraine. Our findings are to some extent consistent with the ratings of international agencies and journals. For other surveyed countries received a more pessimistic forecast for investors than in the same ratings. Thus, it can be concluded it is expedient to use the permutation entropy to monitor and model stock markets in order to identify their states, and to provide investors with the recommendations on the investment attractiveness of the countries.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

ABBREVIATIONS

ASEAN	Association of Southeast Asian Nations
EU-27	The 27 European Union countries
Fig.	Figure
GSLI	Global Services Location Index
MARKOV	A Markov chain is a stochastic model
PermEn	Permutation entropy
PROMETHEE	Preference Ranking Organization METHod for Enrichment of Evaluation
SEE-6	The six countries of South East Europe (Albania, Bosnia and Herzegovina (BiH), Kosovo, FYR Macedonia, Montenegro, Serbia)
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
UNCTAD	United Nations Conference on Trade and Development

WORLD STOCK INDICES

COUNTRY	SYMBOL	NAME
Canada	^GSPTSE	S&P/TSX Composite index
China	^000001.SS	SSE Composite index
France	^FCHI	CAC40
Germany	^GDAXI	DAX PERFORMANCE INDEX
Hong Kong	^HSI	HANG SENG INDEX
Japan	^N225	Nikkei225
Korea	^KS11	KOSPI Composite Index
United Kingdom	^FTSE	FTSE100
US	^GSPC	S&P500
Ukraine	^PFTS	PFTS

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