DETERMINATION OF THE RISK-FREE RATE OF RETURN ON AN INVESTMENT EFFICIENCY BASED ON THE FRACTAL MARKETS HYPOTHESIS

ANDRII KOZLOVSKYI, DARIA BILENKO, SERHII KOZLOVSKYI, RUSLAN LAVROV, OLEH SKYDAN, NATALYA IVANYUTA

ABSTRACT
In determining the economic efficiency of an investment project, the rationale and choice of the discount rate is the most difficult step. The methods of investment assessment are built on the rate of return used to discount future cash flows back to their present value. To increase the accuracy of calculations and reduce the subjective assessments of experts, statistical methods are used. The market process is known to be stochastic. Therefore, investors know that the application of statistical methods is not practical, and thus prefer to use their intuition and professional experience. The alternative group of methods such as the Fractal Markets Hypothesis is not widely used because it is difficult to carry out calculations according to the proposed formulas in practice. In this paper, the aim is to propose a method for determining the risk-free rate of return on an investment project based on the Fractal Markets Hypothesis for identifying long-term dependence and assessing the contribution to the total result of changes in inflation. The objective of the study is the determination of the risk-free rate of return on an investment project. The real risk-free rate is calculated as the existing inflation rate. The result of this paper is the definition of inflation boundaries for Poland, Ukraine and Russia, which may be used for determining the risk-free rate of return on an investment project.

KEY WORDS
Economic efficiency, investment project, risk, rate of return, Poland, Ukraine, Russia.

DOI: 10.23762/FSO_VOL8_NO3_4

ANDRII KOZLOVSKY
andrii.kozlovskyi@miratechgroup.com
Miratech, Inc., New York, United States

DARIA BILENKO
e-mail: belenkodaria1@gmail.com
University of State Fiscal Service of Ukraine, Irpin, Ukraine

SERHII KOZLOVSKYI[1]
e-mail: s.kozlovskyy@donnu.edu.ua
Vasyl' Stus Donetsk National University, Vinnytsia, Ukraine

RUSLAN LAVROV
e-mail: lavrus2017@gmail.com
Chernihiv National University of Technology, Chernihiv, Ukraine

OLEH SKYDAN
e-mail: skydanolegV@ukr.net
Zhytomyr National Agroecological University, Zhytomyr, Ukraine

NATALYA IVANYUTA
e-mail: natalaivanuta9@gmail.com
Donetsk Law Institute of the Ministry of Internal Affairs of Ukraine, Kryvyi Rih, Ukraine

[1] Corresponding author

Introduction

When making an investment decision, a rational investor agrees to implement his project only if his future return is higher than the alternative and available on the market. In order to determine the future return on an investment project, a discount rate is used as a percentage value, allowing one to bring the cost of future cash flows to their current value equivalent (Spier, 2014). The depreciation of future income is influenced by many factors (Ackerer and Filipović, 2020), including inflation, risks of non-receipt or loss of income, lost profits arising from the emergence of a more prof-

Paper received: 14 May 2020 • Paper revised: 2 July 2020 • Paper accepted: 16 July 2020

itable alternative investment opportunity in the process of the implementation of the investment decision, and many others (Graham et al., 2006).

In order to compare investment options for different risk levels, the discount rate is usually divided into two components (Szetela et al., 2020), one of which is the risk-free rate and the other of which is rate risk (Shearn, 2011; Yousuf et al., 2019).

The risk-free rate of return is the same for all investors and is exposed only to the risks of the economic system, such as macroeconomic factors, political events, legislative changes, emergency man-made and natural events, etc. The risk-free rate reflects the lowest possible return acceptable to the investor.

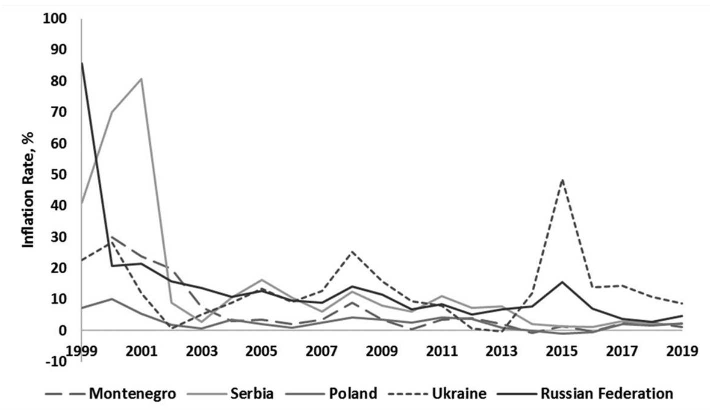
The risk-free rate is divided into two types. The first type is the interest rate for typical types of investments with the lowest risks (Smit and Polakow, 2018). The second type is the real risk-free rate, which is calculated using the existing inflation rate on the basis of the nominal rate minus the existing inflation rate (Graham et al., 2006).

Inflation very often causes devaluation, which is the official lowering of the value of a country's currency (Adrian et al., 2018). With devaluation, an official depreciation of the national currency against hard currencies within a fixed exchange-rate system set by the monetary authorities is observed (Bernholz, 2016). The hard currency is the US dollar, British pound sterling, Canadian dollar, Japanese yen, Swiss franc, Australian dollar, as well as the FRG and French francs, which were later replaced by the euro (Steinberg, 2015).

A significant number of developed countries are characterised by a low level of inflation. In advanced economies, the inflation rate does not rise by more than 2% (Turkington and Yazdani, 2020). According to the World Economic Outlook published by the International Monetary Fund, in Germany the annual percentage change in the inflation rate in 2019 was 1.5%, in France it was 1.2%, and in the United Kingdom it was 1.8%. With such an inflation rate, it is convenient to take the nominal risk-free rate as the base indicator.

For countries which both do not use hard currency and have an inflation rate of above 2% per year (Hadhri and Ftiti, 2019), the task of determining the real risk-free rate considering the level of currency devaluation becomes urgent. Using the example of five countries from Eastern Europe and the Balkan Peninsula, let us consider how the inflation rate changed from 2000 to 2019 (Figure 1):

Figure 1. Inflation dynamics over 20 years



Source: Own elaboration based on International Monetary Fund.

Figure 1 shows that, in the countries selected for analysis, the inflation rate remained approximately constant for several years, and then suddenly increased. If a similar daily schedule were to be constructed, it would become obvious that in the years during which inflation changed dramatically, most days remained unchangeable during the year. Great leaps in exchange rates are common, because they change over time under the influence of numerous factors that are not only economic, but also political (Piterbarg, 2018; Stukalo et al., 2019). In such conditions, it is difficult to determine the inflation level using statistical methods, for example as an average indicator for a certain period. The investor has to choose a risk-free rate on his own. The investor does not use mathematical models, but rather relies on his feelings about what kind of risk-free rate can be expected in a country. Often, the choice of a risk-free rate is determined intuitively based on previous knowledge of what has happened in that country. However, a person cannot remember a large amount of information, and the exclusive use of professional intuition in investment decision making can lead to catastrophic mistakes. On the contrary, statistical techniques make it possible to draw meaningful conclusions from masses of data.

The purpose of the study is to propose and test a method for determining the risk-free rate of return on an investment project for identifying long-term dependence using tools applicable in scientific measurements.

1. Literature review

Today, there are more than a dozen ways to choose or calculate the risk-free rate. All such methods can be divided into two groups. The first group of intuitive or expert methods for choosing a risk-free rate of return on an investment project consists of interviewing and averaging the subjective opinions of various specialists about the level of expected return on a particular investment. In this case, the choice of risk-free rate is not mathematically justified and is highly subjective (Antonacci, 2014). For example, the moderation effect of the personality factor of conscientiousness on the relationship between skills and risk assessment has been examined (Mansour et al., 2020; Kozlovskyi et al., 2010). Zhou and Wang (2018) defined three construction equations of weight vectors based on the risk preferences of decision-makers.

The second group includes mathematical methods for determining the risk-free rate of return. Bali and Zhou (2016) focus on economic uncertainty and propose a two-factor conditional model with time-varying market risk and uncertainty. A paper by Hašková and Fiala (2019) covers the fundamentals of the general fuzzy model of the foreign investment “risk” estimation of selected countries in Europe and Asia.

One of the classic mathematical approaches to determining a theoretical risk-free interest rate is Irving Fisher’s concept of inflationary expectations (2018), which is based on the theoretical costs and benefits of holding a currency. The concept is described by the following formulas:

$$R_n = R_r + J_{inf} + R_r * J_{inf} \quad (1)$$

$$R_r = R_n - J_{inf}/1 + J_{inf} \quad (2)$$

where: R_n – the nominal interest rate; R_r – the real interest rate; J_{inf} – the inflation index (annual inflation rate).

Despite the widespread recognition and popularity of the concept proposed by Fisher, the question of assessing the level of inflation remains open. There are two possible approaches:

- assessing the previous inflation rate in the country in order to come to a conclusion about what the level of

inflation may be in the future;
- determining the expected level of inflation without reference to past trends (Bernholz, 2016).

The expected inflation level is traditionally determined using questionnaires. Respondents are asked to answer a number of questions related to their inflationary expectations and inflation in general. Obviously, when evaluating the expected level of inflation, most respondents suppose that past changes in exchange rates will affect their future value (Crayton, 2016). This approach is consistent with the thesis that the foreign exchange market has a long-term memory on long-term investment horizons (Peters, 1994).

Practical experience in assessing the level of inflation shows that the most effective way is the Fractal Markets Hypothesis (FMH). In accordance with FMH, most time series in the financial markets are characterised by the effects of long-term memory. This means that today's market activity affects future activity for a long time into the future. Some price changes are due to changes in fundamental information and the uncertainty of future cash flow trends. Long-term memory causes trends and cycles (Ingolfsson et al., 2020). These cycles may be erroneous because they are a function of the effect of long-term memory and an accidental change in market bias (Peters, 1996).

To check the presence of long-term dependence in a time series, Rescaled Range Analysis (R/S) is used. One of the main advantages of R/S analysis, unlike most widely used statistical criteria, is that it is not based on any assumptions about the output data organisation, or the distribution it obeys. It is the most important factor when studying phenomena such as stock prices or currencies, for which the deliberate falsity of Gaussian approaches has been confirmed by numerous studies (Raimundo and Okamoto, 2018). The R/S formula allows one to determine for different time periods whether the scope will be greater or less than that which can be expected in cases when each individual element of the output data will not depend on the previous figures. If the scope differs from that which is expected, then a number of profitable or unprofitable moments shift the extreme values further than in the case of their occurrence by chance (Uthayakumar and Jayalalitha, 2014).

The range R is the distance that the system moves in time n. For Brownian motion, Einstein found that the distance travelled by a randomly wandering particle increases in proportion to the square root of time.

For systems which, unlike Brownian ones, are not independent, Hurst has proposed a more general formula (Shaikh, Rabbani, 2014):

$$(R/S)_n = cn^H \quad (3)$$

where: n – the number of time series elements; c – constant; H – the Hurst parameter.

Obviously, for Brownian motion or any other process based on independent events, the following equations must be satisfied: $c = 1$, $H = 0.5$. If $H > 0.5$, then the process has long-term memory.

Despite the logic and validity of the proposed approach to determining the risk-free rate of return on an investment project, the question of using Formula 3 in practice remains difficult.

2. Methodology

The proposed method for determining the risk-free rate of return on an investment project is based on the Fractal Markets Hypothesis for identifying long-term dependence and assessing the contribution to the total result of changes in inflation.

The methodology for the risk-free rate of return on an investment project consists of the following sequence of steps (Koziuk et al., 2019):

1. Take data on changes in the exchange rate over a period of time. It is possible to display the change in the exchange rate by day, by week, and by month. This depends on the investment horizon, as the longer it is, the greater the difference between neighbouring values should be, and vice versa. Data needs to be taken for more than 400 periods. The result will be the time series *x* from *m* consecutive values $x = x_1, x_2, \dots x_m$.

2. To calculate by means of formula 4, the dependence of R/S on *n* should be obtained. For this, it is necessary to estimate the cumulative normalised range by changing the scale or normalising the data. This can be done by subtracting the sample average:

$$y_1 = x_i - \overline{x} \tag{4}$$

$$y_i = x_i - \overline{x} + y_{i-1} \tag{5}$$

where: y_i – the normalised exchange rate; x_i – the exchange rate; $\underline{x}$ – the exchange rate average value of a sample of size *n*.

The last value y (y_n) is always zero, because the cumulative series has an average value of zero.

3. The range R_n of time series x is determined by the formula:

$$R_n = \max(y_1, \dots, y_n) - \min(y_1, \dots, y_n) \tag{6}$$

where: $(y_1, \dots, y_n)$ – the cumulative normalised time series.

The index n means that the range is determined for the time series containing n elements.

The R/S value of equation (3) is called the normalised range because it has a zero mean and is expressed in terms of the standard deviation:

$$\left({}^{R}/_{S}\right)_n = \frac{\max(y_1 - y_n) - \min(y_1 - y_n)}{S_n} \tag{7}$$

where: $(y_1, \dots, y_n)$ – the cumulative normalised time series; S_n – the standard deviation of a sample of size n.

If the function $(R/S)n$ is constructed in the logarithmic coordinates on both axes, then the solution of equation (3) for c and H is found using linear approximation (the method of least squares), so that *c* is the distance cut off by the straight line on the *y* axis, and H is the angle of the line to the x axis.

4. For determining the risk-free rate of return on an investment project in addition to identifying long-term dependence and expected trends, it is important to find the "jump" magnitude in the exchange rate. If all the relative currency changes are taken in the absolute value of a number and ranked in descending order, a typical Pareto curve will be obtained (Matthew, 2019). To find the average change in the value of currency for dynamic periods, i.e. the 20% as given by the Pareto principle, it is necessary to divide the total change in the entire period by the number of dynamic period

$$(R/S)_n = cn^H \tag{8}$$

where: $(x_1, \dots, x_t)$ – the currency changes time series; D – the number of dynamic periods; m – the number of observations.

5. Using the R/S value (formula 7) and the average change in the value of currency (formula 8), the average value and predictability of the change in the exchange rate can be concluded. Various methods of combination of these parameters can be used: for example, to calculate the confidence interval, which expands the average change in the value of currency for dynamic periods in both directions by the value of the Hurst parameter.

As part of the study, it is proposed that the risk-free rate of return on an investment project determine the range of changes as follows:

$$\overline{x_t^D} = \overline{x_t^D} \pm \overline{x_t^D} \cdot (1 - H) \tag{9}$$

where: $\overline{x_t^D}$ – the average change in the value of currency for dynamic periods; H – the Hurst parameter.

The proposed method for determining the risk-free rate of return on an investment project based on the Fractal Markets Hypothesis for identifying long-term dependence and assessing the contribution to the total result of changes in inflation is easily implemented in any table processor, including MS Excel.

3. Results

In practice, the method for determining the risk-free rate of return on an investment project based on the Fractal Markets Hypothesis is applied for three countries of Eastern Europe, namely Poland, Ukraine and Russia. These countries do not use hard currency.

The results of the implementation of this method are also presented by a sequence of steps:

1. For Poland, Ukraine, and Russia, a time series of changes in the exchange rate was constructed from 02/01/2012 to 02/01/2020. The exchange rate is presented for each week; a total of 492 consecutive values were taken.

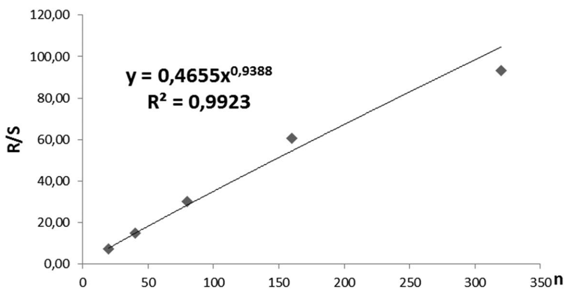
2. To estimate the cumulative normalised range, all values of the changes in the exchange rate time series were divided into intervals of 20 values, then 40, 80, 160, and 320. The result is a data set of 20, 40, 80, 160, and 320 values for each country.

3. Subsequently, using formulas 6-7 for each data set, the normalised exchange rate, the range Rn, and the R/S indicator were obtained. Calculations of the R/S indicator and the graphs of the exchange rate for Poland, Ukraine and Russia are presented (Fig. 2).

Figure 2. Function (R/S)n of the dollar to the national currency rate of a) Poland; b) Ukraine; c) Russia

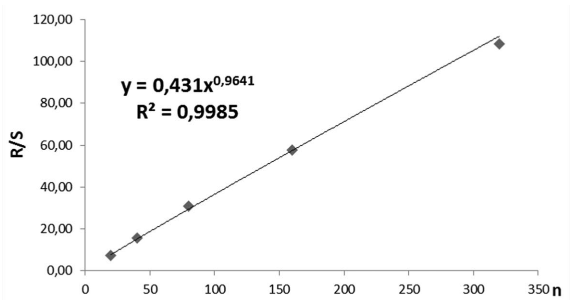
a)

n	R/S indicator
20	7.22
40	15.15
80	30.21
160	60.69
320	93.43



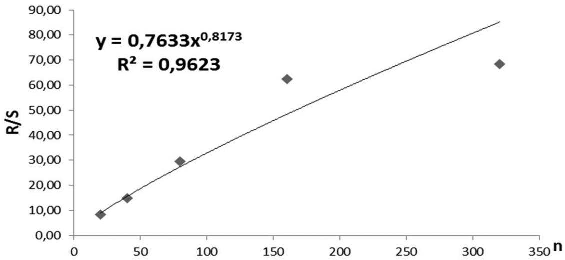
b)

n	R/S indicator
20	7.38
40	15.60
80	30.83
160	57.68
320	108.43



c)

n	R/S indicator
20	7.22
40	15.15
80	30.21
160	60.69
320	93.43



Source: Own elaboration.

As can be seen in Figure 1, in each case, the Hurst parameter significantly exceeds 0.5, which goes to confirm the presence of long-term memory. For Poland, the Hurst parameter is 0.9388 (Fig. 1a), for Ukraine it is 0.9641 (Fig. 1b), and for Russia it is 0.8173 (Fig. 1c). The closer the Hurst parameter is to 1, the more reliable the forecast for changes in the exchange rate is. Therefore, if the Ukrainian and Polish national currencies change in price (Kozlovskyi et al., 2011), the more likely they are to continue moving in the same direction. The Russian currency may change its movement in a more unpredictable way.

4. To find the average change in the value of currency for dynamic periods by means of formula 8, the relation of two adjacent values of the time series *x* should be found. It is then necessary to take 20% of the relative changes in modulus, ranked from maximum to minimum, and calculate the average of the total changes in these 20% of dynamic weeks.

The calculations showed that the number of dynamic periods is 98 weeks, and the number of unchangeable periods is 394 weeks. In Poland, during dynamic periods, the exchange rate fluctuated an average of 2.4% every week, in Ukraine it fluctuated an average of 4.7%, and in Russia it fluctuated an average of 3.8%. In the unchangeable period, the weekly change of currency was 0.65% on average in Poland, 0.44% in Ukraine, and 0.79% in Russia.

Currency and inflation risks are lowest in Poland, making this country most attractive for investors. In Ukraine there are both the greatest changes in the dynamic periods and the smallest changes in the unchangeable periods. For investors, it means that the profitability of the investment project can be highest in comparison with Poland and Russia only on a short-term investment horizon. In Russia, the average changes in the exchange rate in the dynamic and unchangeable weeks indicate the constant fluctuations on both long- and short-term investment horizons. However, at the same time, currency and inflation risks are highest compared to Poland and Ukraine.

5. The real risk-free rate of return on an investment project in different countries should be determined depending on the expected level of inflation. Using formula 9, a confidence interval is calculated (Table 1).

Table 1. The range of changes in the exchange rate in Poland, Ukraine and Russia

Country	Average change in the value of currency for dynamic periods adjusted for the Hurst parameter	Upper bound of inflation	Lower bound of inflation
Poland	2.38% ± 0.15%	2.23%	2.52%
Ukraine	4.67% ± 0.17%	4.50%	4.84%
Russia	3.84% ± 0.70%	3.14%	4.55%

Source: Own elaboration.

As can be seen from Figure 1, the bounds of inflation may be from 2.23% to 2.52% for Poland, from 4.50% to 4.84% for Ukraine, and from 3.14% to 4.55% for Russia.

The proposed confidence interval of changes in the exchange rate can be used by the investors to determine the risk-free rate that investors expect to earn after inflation.

4. Discussion

While the Fractal Markets Hypothesis for identifying long-term dependence and assessing the contribution to the total result of changes in inflation provide a more accurate presentation of markets, the Efficient-Market Hypothesis (EMH) resides at the front position of the financial theory. EMH states that asset prices reflect all available information that is immediately and fully reflected in the financial market (Chiara, 2016). The strong form of EMH assumes that prices incorporate all the available information on a market, which includes historical financial information. A number of research papers have proven that strong forms of EMH are not supported by financial data in the medium and long term. On the other hand, in many papers based on EMH, the efficiency of capital markets is confirmed (Ţiaţan, 2015).

Without underestimating EMH, it should be noted that the proposed approach for determining the risk-free rate of return on an investment project focuses precisely on the long-term period.

Most of the proposed papers devoted to investment assessment would benefit if the proposed approach for determining the risk-free rate of return on an investment project based on the Fractal Markets Hypothesis were applied. For example, Polish scientists (Jackowicz, Kozłowski, Mielcarz, 2016) undertook similar research investigating the phenomenon of financial constraints in investment activities in Poland. When determining the dependent variables of investments, the model did not include the real risk-free rate of return on an investment, while other indicators such as financial leverage, the market value to book value ratio and the return on sales ratio were included.

Mykhayliv and Zauner (2017) empirically investigated the impact of different ownership groups on companies' investment in Ukraine by means of a novel dynamic investment model where investment is based both on present and historical levels of profitability. As well as in the proposed approach for determining the risk-free rate of return on an investment project based on the Fractal Markets Hypothesis, the authors found out that the past level of profitability significantly affects investment. However, the study concerned only Ukraine, and a comparative analysis of other countries was not carried out.

The results of this study could complement the effective planning system proposed by Ivanisevic et al (2020) with an indicator such as inflation from the perspective of investment efficiency.

Ilina, Streltsova, Borodin, and Yakovenko (2019) proposed an assessment mechanism of the effectiveness of public investment in R&D. Despite the fact that the main source of investment is foreign grant financing carried out on a competitive basis, the issue of the reliability of exchange rate forecasts was not considered at all.

The limitation of the proposed approach for determining the risk-free rate of return on an investment project is that it can be used only for countries that both do not use hard currency and where the inflation rate is above 2% per year.

This paper contributes to the existing literature by adding to studies that determine the risk-free rate of return on an investment project.

Conclusions

In the article, a method for determining the risk-free rate of return on an investment project based on the Fractal Markets Hypothesis for identifying long-term dependence and assessing the contribution to the total result of changes in inflation is proposed. This allows the authors to put Rescaled Range Analysis into practice. The results of this method are conclusions about the reliability of the forecast for changes in the exchange rate for Poland, Ukraine and Russia, currency and inflation risk assessment, and the definition of inflation boundaries for Poland, Ukraine and Russia.

For Poland, the forecast for changes in the exchange rate is reliable, while currency and inflation risks are low. The deviation range for the risk-free rate does not exceed 5% in each direction.

For Ukraine, the forecast for changes in the exchange rate is reliable, while currency and inflation risks are low only on short-term investment horizons. During the long-term investment horizon, risks may increase. The deviation range for the risk-free rate does not exceed 5% in each direction.

For Russia, the forecast for changes in the exchange rate is less reliable, while currency and inflation risks are medium, both on short-term and long-term investment horizons. The deviation range for the risk-free rate should reach 15% in each direction.

The proposed method for determining the risk-free rate of return on an investment project based on the Fractal Markets Hypothesis for identifying long-term dependence and assessing the contribution to the total result of changes in inflation can be considered as a separate mathematical model or used as support for expert methods of choosing the risk-free rate of return of an investment project. Put another way, the contribution to the science of the proposed method is the new practical application of the Fractal Markets Hypothesis. Investors can put formulas 4-9 into practice. A possible future direction for research is to improve the proposed method for determining the risk-free rate of return so that it can be applied for countries where the inflation rate is above 2% per annum but hard currency is used.

In terms of financial globalisation, the role of various investments such as concessions, joint ventures, special economic zones and international leasing is reinforced. This requires the improvement of new scientifically-based methods which have been proven to be effective but have not yet been used to determine the risk-free rate of return on an investment efficiency. This article was the first attempt to use the Fractal Markets Hypothesis to identify long-term dependence and assess the contribution to the total result of changes in inflation, based on the example of three countries. The methodology used may be of interest not only to scientists, but also to various analytical companies. For real investments, as well as the development of priority investment programs, it is important to understand the benefits of each participant in the investment market. The results of the research offer international organisations and authorities an opportunity to promptly analyse the financial efficiency of investment projects.

References

Ackerer, D., Filipović, D. (2020), Linear credit risk models, Finance and Stochastics, 24, 169-214. https://doi.org/10.1007/s00780-019-00409-z

Adrian, T., Estrella, A., Song Shin, H. (2018), Risk-taking channel of monetary policy, Financial Management, 48(3), 725-738. https://doi.org/10.1111/fima.12256

Antonacci, G. (2014), Dual momentum investing: An innovative strategy for higher returns with lower risk. McGraw-Hill Education, N.J.

Bali, T., Zhou, H. (2016), Risk, uncertainty, and expected returns, Journal of Financial and Quantitative Analysis, 51(3), 707-735. https://doi.org/10.1017/S0022109016000417

Bernholz, P. (2016), Monetary regimes and inflation: History, economic and political relationships, Cheltenham: Edward Elgar Publishing.

Chiara F. Del Bo. (2016), The rate of return to investment in R&D: The case of research infrastructures, Technological Forecasting and Social Change, 112, 26-37. https://doi.org/10.1016/j.techfore.2016.02.018

Crayton, L.A. (2016), Inflation: What it is and how it works (Economics in the 21st Century), Berkeley Heights, NJ: Enslow Pub Inc.

Fisher, I. (2018), The theory of interest as determined by impatience to spend income and opportunity to invest it blurb, San Francisco, CA: Martino Fine Books.

Graham, B., Zweig, J., Buffett, W.E. (2006), The intelligent investor: The definitive book on value investing. A book of practical counsel (revised edition), New York: Harper Business.

Hadhri, S., Ftiti, Z. (2019), Asset allocation and investment opportunities in emerging stock markets: Evidence from return asymmetry-based analysis, Journal of International Money and Finance, 93,187-200. https://doi.org/10.1016/j.jimonfin.2019.01.002

Hašková, S., Fiala, P. (2019), A fuzzy approach for the estimation of foreign investment risk based on values of rating indices, Risk Management, 21, 183-199. https://doi.org/10.1057/s41283-019-00051-1

Ilina, I., Streltsova, E., Borodin, A., Yakovenko, I. (2019), The impact of public investment on the competitiveness of the Russian R&D sector, International Journal of Mechanical Engineering and Technology, 10(1), 1128-1140.

Ivanisevic, A., Losonc, A., Radisic, M., Njegovan, M., Pavlovic, A. (2020), Development of an effective planning model for improving financial performance, Forum Scientiae Oeconomia, 8(1), 67--81. https://doi.org/10.23762/FSO_VOL8_NO1_5

Ingolfsson, A., Almehdawe, E., Pedram, A., Tran, M. (2020), Comparison of fluid approximations for service systems with state-dependent service rates and return probabilities, European Journal of Operational Research, 283(21), 562-575. https://doi.org/10.1016/j.ejor.2019.11.041

International Monetary Fund. Inflation rate, average consumer prices, retrieved from: https://www.imf.org/external/datamapper/PCPIPCH@WEO/OEMDC/ (accessed 1 February 2020))

Jackowicz, K., Kozłowski, Ł., Mielcarz, P., (2016), Financial constraints in Poland: The role of size and political connections, Argumenta Oeconomica, 36, 225-239. DOI: 10.15611/aoe.2016.1.09

Kaletnik, G.M., Zabolotnyi, G.M., Kozlovskyi, S.V. (2011), Innovative models of strategic management economic potential within contemporary economic systems, Actual Problems of Economics, 4(118), 3-11.

Koziuk, V., Hayda, Y., Dluhopolskyi, O., Klapkiv, Y. (2019), Stringency of environmental regulations vs. global competitiveness: Empirical analysis, Economics and Sociology, 12(4), 264-284. DOI: 10.14254/2071-789X.2019/12-4/17

Kozlovskyi, V., Gerasymenko, Y. Kozlovskyi, S. (2010), Conceptual grounds for construction of support system for investment decision-making within agroindustrial complex of Ukraine, Actual Problems of Economics, 5(107), 263-275.

Matthew, E. (2019), Pricing flexibility under rate-of-return regulation: Effects on network infrastructure investment, Economic Modelling, 78, 150-161. DOI: 10.1016/j.econmod.2018.09.016

Mansour, A., Ahmi, A., Popoola, A. (2020), The personality factor of conscientiousness on skills requirement and fraud risk assessment performance, International Journal of Financial Research, 11(2), 405-415. https://doi.org/10.5430/ijfr.v11n2p405

Mykhayliv, D., Zauner, K. (2017), The impact of equity ownership groups on investment: Evidence from Ukraine, Economic Modelling, 64, 20-25. DOI: 10.1016/j.econmod.2017.03.005

Peters, E.E. (1994), Fractal market analysis: Applying chaos theory to investment and economics (1st edition), Hoboken, NJ: Wiley.

Peters, E.E. (1996), Chaos and order in the capital markets: A new view of cycles, prices, and market volatility (2nd edition), Hoboken, NJ: Wiley.

Piterbarg, V. (2018), The optimal investment problem in stochastic and local volatility models, Journal of Investment Strategies, 7(4), 1-25. https://doi.org/10.21314/JOIS.2018.104

Prokopenko, O., Shmorgun, L., Kushniruk, V., Prokopenko, M., Slatvinska, M., Huliaieva, L. (2020), Business process efficiency in a digital economy, International Journal of Management, 11(3), 122-132.

Raimundo, M.S., Okamoto, J.Jr. (2018), Application of Hurst Exponent (H) and the R/S analysis in the classification of FOREX securities, International Journal of Modeling and Optimization, 8(2), 116-124. DOI: 10.7763/IJMO.2018.V8.635

Shaikh, Y.H., Rabbani, G. (2014), Gold price data analysis using rescaled range (R/S) analysis, International Journal of Economics, 4(1), 7-14.

Shearn, M. (2011), The investment checklist: The art of in-depth research, Hoboken, NJ: Wiley Finance.

Smit, S., Polakow, D. (2018), The global currency tango – the relationship between the carry trade, emerging/commodity currencies and risk, Investment Analysts Journal, 47(4): 285-303. https://doi.org/10.1080/10293523.2018.1485217

Spier, G. (2014), The education of a value investor: My transformative quest for wealth, wisdom, and enlightenment, New York: St. Martin's Press.

Steinberg, D.A. (2015), Demanding devaluation: Exchange rate politics in the developing world. Cornell studies in money, Ithaca: Cornell University Press.

Stukalo, N., Simakhova, A., Shmarlouskaya, H. (2019), Special features of formation of the source base for economic socialization, Problems and Perspectives in Management, 17(3), 271-279. http://dx.doi.org/10.21511/ppm.17(3).2019.22

Szetela, B., Mentel, G., Mentel, U., Bilan, Y. (2020), Directional movement distribution in the bitcoin markets, Inzinerine Ekonomika-Engineering Economics, 31(2), 188-196. https://doi.org/10.5755/j01.ee.31.2.25162

Ţiţan, A. (2015), The efficient market hypothesis: review of specialized literature and empirical research, Procedia Economics and Finance, 32, 442-449. https://doi.org/10.1016/S2212-5671(15)01416-1

Turkington, D., Yazdani, A. (2020), The equity differential factor in currency markets. Financial Analysts Journal, 76(2), 70-81. DOI: 10.1080/0015198X.2020.1712924

Uthayakumar, P., Jayalalitha, G. (2014), A comparison of fractal dimension algorithms by Hurst exponent using gold price time series, International Journal for Research in Applied Science & Engineering Technology, 6(2), 1210-1215.

Yousuf, A., Haddad, H., Pakurar, M., Kozlovskyi, S., Mohylova, A., Shlapak, O., Janos, F. (2019), The effect of operational flexibility on performance: A field study on small and medium-sized industrial companies in Jordan, Montenegrin

Journal of Economics, 15(1), 47-60. DOI: 10.14254/1800-5845/2019.15-1.4

Zhou, L., Wang, Q. (2018), Decision-maker's risk preference based intuitionistic fuzzy multiattribute decision-making and its application in robot enterprises investment, Mathematical Problems in Engineering, 1-6. DOI: 10.1155/2018/1720189

Andrii Kozlovskyi, Ph.D., As. Professor, Director, Employee Experience. Miratech, Inc. USA. Ternopil National Economic University, Ukraine. Scientific interests: information systems, information technology, technological systems, economic security. ORCID no. 0000-0001-9697-1511

Daria Bilenko, Ph.D., Associate Professor of the L.L. Tarangul Department of Finance, University of State Fiscal Service of Ukraine. Scientific interests: investments, economic processes simulating modelling. ORCID no. 0000-0002-6220-8101

Serhii Kozlovskyi, D.Sc., Professor, Professor of the Department of Entrepreneurship, Corporate and Spatial Economics of Vasyl' Stus Donetsk National University, Ukraine. Scientific interests: management, modelling and forecasting of difficult economic processes with the use of the most modern mathematical theories. ORCID no. 0000-0003-0707-4996

Ruslan Lavrov, D.Sc., As. Professor, Professor of the Chernihiv National University of Technology, Ukraine. Scientific interests: problems of development of the agrarian sector of Ukraine, marketing, finance. ORCID no. 0000-0002-9655-4467

Oleh Skydan, D.Sc., Professor, Rector of the Zhytomyr National Agroecological University, Ukraine. Scientific interests: provision of economic and food security, problems of development of the agricultural sector of Ukraine. ORCID no. 0000-0003-4673-9620

Natalya Ivanyuta, D.Sc., As. Professor, Professor of the Law Department, Donetsk Law Institute of the Ministry of Internal Affairs of Ukraine. Scientific interests: legal support for the development of Ukraine. ORCID no. 0000-0001-9177-9280