Journal of Business Economics and Management
ISSN 1611-1699 / eISSN 2029-4433
2020 Volume 21 Issue 1: 136–156
https://doi.org/10.3846/jbem.2020.11768

STOCHASTIC INFORMATIVE EXPERT SYSTEM FOR INVESTMENT

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Received 28 April 2019; accepted 14 October 2019

Abstract. The stochastic nature of investment process implies that it should be treated not unambiguously. Instead of concentrating only on possible return, it is worth analysing three parameters when we discuss the future investment results. These parameters are return possibility, reliability of this possibility, and the riskiness. The stochastic informative expert system for investment allows to analyse the behaviour of financial markets, forecasting the dynamics of stock prices and, along with that, rationally allocating investment resources. The proposed system is based on the adequate portfolio model, previously developed by the authors. Considering the real-time characteristics of financial markets, the system can be useful for individual investors, as well as for institutional investors, such as investment funds. Also, the authors propose the original risk tolerance determination methodology, which divides investors into three categories according their risk tolerance. The system can be applicable not only to capital markets, but also to other business or macroeconomic processes. As an example, a portfolio of the interaction of macroeconomic indicators with USA, UK, and Lithuanian data is developed. Such results could be useful for economists and governments in order to attain the higher value added in a particular country.

Keywords: stochastic expert system, investment, portfolio, stochastic optimization, risk tolerance, macroeconomic indicators.

JEL Classification: G11, G17, O11.

Introduction

The main objective of the paper is to present the model of stochastic informative expert system, which adapts to the search of optimal investment resources' allocation for financial markets and business, as well as macro projects. An exceptional function attributed for the mentioned stochastic informative expert system is the ability to reason that stochastic informative manner of efficient investment decision search is not only an innovative means

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of search for investment schemes. This is also a natural instrument to assess the investor's risk resistance, or risk tolerance. Thus, the mentioned scheme becomes a key component of the risk management instruments' complex during the extremely risky process – investment decision search (Ortner et al., 2017; Liu & Jiang, 2019).

Analytical-informational task of the paper is to reveal how strongly the stochastic investment management manner could affect the result of the certain investment type. Also, it is aimed to determine how this management style should be matched with risk resistance powers of an investment subject. There is no doubt that in order to structure the problem for analytical solution, it is being revealed that this is a problem showing how the information flows of great scope, material, human and technological resources turn into value or costs. This process depends on historical data, which, in turn, allow concretizing the required parameters in a set of big dependency. Thus historical market data, or simply, market intelligence (Cavalcante et al., 2016; Liang & Liu, 2018) provides the possibility to objectively assess the final results of the resources utilized, as well as the analytical model of formation of these results. By doing so, one can obtain higher results by using no additional resources. The reliability indicator of possible value, which is measured quantitatively, is selected as a required feature for this process in the performed research. The mentioned indicator becomes an attribute of the stochastic assessment of perspective, as well as the real factor of the successful result.

The performed research is based on previous studies and newly performed experiments where the information generated by artificial intelligence was used (Buračas et al., 2014; Rutkauskas et al., 2017). Intelligence in general is perceived as the ability to perceive a problem and find out its solution possibilities or outcomes, while artificial intelligence (Wall, 2018; Montes & Goertzel, 2019) is perceived by the authors as the ability of a system to reveal the problem and point out its solution possibilities and outcomes using information sources of reality transformation.

The inputs used for the research are: the real process taking place in the representative financial market, the adaptive and adequate forecasting system for stochastic nature of financial markets, as well as stochastic informative expert system and stochastic optimization systems. Thus the paper attempts to answer the question whether investors (individual investors, mutual and pension funds), with the help of inputs mentioned above, can find out the possibilities of ensuring a high enough investment portfolio return, of course not contradicting the development of the whole analysed market. For such experiment, a representative group of Swiss stock market has been used. Portfolio solutions were generated using adequate portfolio model and stochastic expertise.

The structure of the paper is as follows. Section 1 presents a thorough literature analysis, where other possible decision support systems for portfolio formation and management are described. Section 2 covers the research methodology where the expert system and the process of expert rating are presented. Section 3 is devoted to the practical application of stochastic optimization system for portfolio formation. Section 4 presents the visualization of results. Section 5 points out the results of including the investor's risk tolerance into the decision-making. The experimental portfolio of the interaction of macroeconomic indicators is developed in Section 6. Finally, conclusions, limitations and future research directions are described.

1. Literature review

Expert systems are gaining popularity in many fields of human activity. There are expert systems for semantic reasoning (Savage et al., 2019). The systems can be applied in estimations, for example, for estimating fuzzy linear regression model parameters (Icen & Gunay, 2019) or in probabilistic risk assessment (Yazdi et al., 2019). Also, expert systems can be implemented in quite distinct fields of research from investment management, for example, for fire safety (Chojnacki et al., 2019).

Moreover, expert knowledge is necessary in today‘s world of information and technologies. Even with the absence of adequate expert system, expert knowledge play an important role in various processes in a certain form. Pointing out again quite different field of research from financial markets, it is worth noticing marine shipment and related warehousing and gathering of stock (Chrysafi et al., 2019). In their research the authors state that expert knowledge can provide information regarding the relative stock status of the products. Also, expert opinion, if corrected for biases, can improve default product stock status assumptions. In general, expert opinions are extremely valuable in different fields of research. If we need to analyse some application of knowledge, not all the elements of required knowledge can be covered by data or conventional analysis instruments. Thus, subjective opinions of experts can provide the required information for an unknown parameter in the form of a probability distribution.

Expert knowledge and expert systems can be used in risk modelling and assessment, including systemic risk (Mezei & Sarlin, 2016), safety risk assessment (Tian et al., 2018), and operational loss (Hurtado, 2010). Risk assessment of IT projects can be performed by an intelligent system that is based on expert knowledge (Pourdarab et al., 2011), while the general project risk has been managed with the help of expert system already in 2003 (Ahuja & Rodder, 2003).

Recalling the object of analysis of the paper, it is worth noticing that investment portfolio decision-making is definitely a key process where expert knowledge is needed. Results of Tam et al. (2006) support the existence of investment expertise in (1) the nature of knowledge, (2) problem solving and information search, and (3) performance. There are many factors that could influence the information processing and performance of the investment expert, and these include personal, cognitive, and contextual elements. For this reason experts are invaluable assets that assist in investment decision-making.

Scientific literature presents several systems that are intended for rational investment decision-making and are partly based on the expert knowledge (Table 1). The majority of these systems are also based on certain expert or artificial knowledge or intelligence. These systems are complex systems, and their proper operation is not without expert knowledge in various elements or subsystems of the whole system.

Many systems described in Table 1 use multiobjective functions or fuzzy algorithms. It is a very broad area of research, nowadays gaining a great popularity. Thus, of course, the analysed systems do not present the full picture of available portfolio selection tools. Some scientists aim to improve the Markowitz model by adding additional parameters or by adjusting the present parameters. For example, Macebo et al. (2017) proposes mean-semivariance portfolio using multiobjective evolutionary algorithms, while Garcia et al. (2019a) extends the mean-semivariance portfolio selection model to a multiobjective credibilistic model that besides risk and return, also considers the price-to-earnings ratio to measure portfolio performance.

Table 1. Investment decision support systems – possible analogues

Authors, years of publication, title of the system	Methods applied	Principle of operation	Result	Technological solution
Kim and Won (2004). UNIK-PRP – Unified Knowledge-based portfolio decision-making system considering Personal Risk Preference	Method of artificial intelligence, knowledge-based system	The system covers four steps: 1. Selection of factors; 2. Determining the risk level acceptable for investor; 3. Generation of a set of assets; 4. Optimal portfolio formation	Optimal portfolio structure	The system is developed on the basis of *UNIK-FWD* and *UNIK-OPT* systems, using *Visual C++ 4.0*, installed into *Windows* operational system
Young and Taib (2009). Decision Support System for Stock Investment Strategy	Artificial neural networks, data mining	The system proposes recommendation for investor after integrating fundamental and technical analysis, as well as the method of artificial neural networks	The system helps to determine – The direction of stock price change; – The assessment of a stock price; – Risk level; – A buy/sell signal	–
Fasanghari and Montazer (2010). Fuzzy Expert System for Portfolio Recommendation	Fuzzy expert systems	Multicriteria analysis and expert assessments	Portfolio structure (particular companies' stocks and their percentage parts) for the five risk levels	MATLAB
Xidonas, Mavrotas, Zopounidis, and Psarras (2011). IPSSIS – Integrated Portfolio Synthesis and Selection Information System	Multiobjective mathematical programming; improved method of ε constraints (AUGMECON)	The model of the system uses four objective functions: 1. Maximization of portfolio return; 2. Maximization of portfolio dividend yield; 3. Minimization of portfolio average absolute deviation; 4. Minimization of portfolio beta	One optimal portfolio out of a set of the proposed portfolios is selected with the help of optimization of the determined parameters	Computer program developed using *Java SE Runtime Environment 6*. Technology: *Microsoft Windows XP*, *Microsoft Office Excel 2003*, *GAMS* modelling system (22.2 or newer version)
Gottschlich and Hinz (2014). Decision support system for stock investment recommendations using collective wisdom	Wisdom of crowds, Sharpe ratio	Wisdom of crowds is included into the investment decision-making. The investor is provided with: 1. Priority list of stocks; 2. Testing of investment strategies;	Rebalancing of portfolio using buying/selling	PHP programmed environment, Web environment linked to MySQL database. For modelling R programming software is used

End of Table 1

Authors, years of publication, title of the system	Methods applied	Principle of operation	Result	Technological solution
		3. Portfolio correction implementing the optimal strategy – by buying and selling assets		
Jalota, Thakur, and Mittal (2017). Credibilistic decision support system for portfolio optimization	L-R fuzzy numbers, entropy – cross entropy algorithm, fuzzy Sharpe ratio, Hybrid Intelligent Algorithm (HIA), “MIBEX-SM” genetic algorithm	Objective functions used: 1. Portfolio return (max); 2. Non-liquidity (min); 3. Risk (min). Constraints: – Risk curve; – Number of assets; – Capital budget; – Maximum part of funds that can be invested into one asset; – No short-selling of securities is allowed	Portfolio structure	–

The presented systems for financial markets are called investment decision-making systems, decision support systems, etc. However, these systems differ substantially from the system being proposed by the authors – the expert stochastic system for investment. First, some analysed systems use rather complex mathematical methods that aggravate the commercialization of the system‘s analogue, as well as sales and its possible application by the broad number of users. Second, not all the systems have the programming support, user interface and environment for everyday use. The expert stochastic system for investment that is being developed solves both obstacles. The model uses the logics of complex adaptive stochastic systems, thus it considers the stochastic nature of investment return. Along with that, the interactive environment that is attractive for user is being currently developed. It will be intended for the use by individual and institutional investors. Also, the big advantage of the proposed system is that the utility function is proposed which considers the acceptable risk level that can be taken by particular investor, while other systems and models lack this feature.

There are also some innovative investment strategies or prediction approaches found in the scientific literature. For example, sustainable investment, or socially responsible investment is gaining great popularity (Sultana et al., 2018). Garcia et al. (2019b) propose multiobjective approach for portfolio selection, which allows to include environmental, social and governance (ESG) scores in the investment decision-making process. Alternatively, hybrid fuzzy neural network is used to predict the direction of stock index (Garcia et al., 2018) that is of great importance when forming the investment portfolio.

The paper proposes a methodology of development resource allocation. It utilizes expert knowledge and is based on the previously developed and elaborated by A. V. Rutkauskas (2000) idea of adequate portfolio model. The idea and technique of adequate portfolio allows the investor to use not only the indicators of profitability and riskiness, but also the concept of guarantee of return. It is worth noticing that guarantee, or reliability, naturally weaves into the logics of decision-making. Collaborating with other co-authors, the idea has been further developed and supplemented: the application peculiarities of the model were disclosed not only for investment portfolio management, but also for rational allocation of other resources (Rutkauskas, 2006; Rutkauskas & Stasytytė, 2011; Rutkauskas & Ostapenko, 2016).

2. Formation methodology of complex adaptive system for optimal allocation of resources intended for development

Since the title of the paper contains the word 'investment', which often is perceived as a monetary or value stock, let us recall that further text will also utilize the broader understanding of investment instruments. However, further discussion should be related to the concretization of the components of the mentioned complex system, as well as their interactions. The key attention will be paid to the ability of the system to ensure a) historical data, b) stochastic informative knowledge, and c) stochastic optimization possibilities for the designated components.

It is worth mentioning the fact regarding the historical data: with its adequate structuring and respective formulation of the questions of interest, it fully presents not only the experience of the market, but also its intelligence. Thus the following needs to be discussed in detail: 1) generation of stochastic informative expert assessments, and 2) required principles of stochastic optimization.

2.1. Generation of the stochastic informative expert assessments

While presenting the research methodology, it is worth discussing the key objectives, utilization principles, organization means and methods of the expert assessment systems.

It is possible to meet the ambiguous point of view towards the application of expert assessments. In such a situation the gathered practice and analytical experience does not allow to distinguish the essence and management possibilities of the analysed phenomena. Also, the way to the full analytical and practical cognition is distant from the physical and economic viewpoint. The mentioned facts merely evidence the exclusivity of expert assessments in the space of extremely complex or urgent problems (Yazdi et al., 2019; Qiu et al., 2018).

Expert self-organization is being formed where the combination of two or more opinions without the proper answer can create a unique cognition environment, as well as in the place where separate elements of the problem being solved can only be seen until the expert team is trooped up. Unsurprisingly, one should not confuse the expert assessment principles with the publicly declared supposed power of democracy: it will be right as we decide. Stepping into the future without the expert assessment glasses can force us to look back. The detailed research methodology applied in the paper based on the expert system is presented in Figure 1.

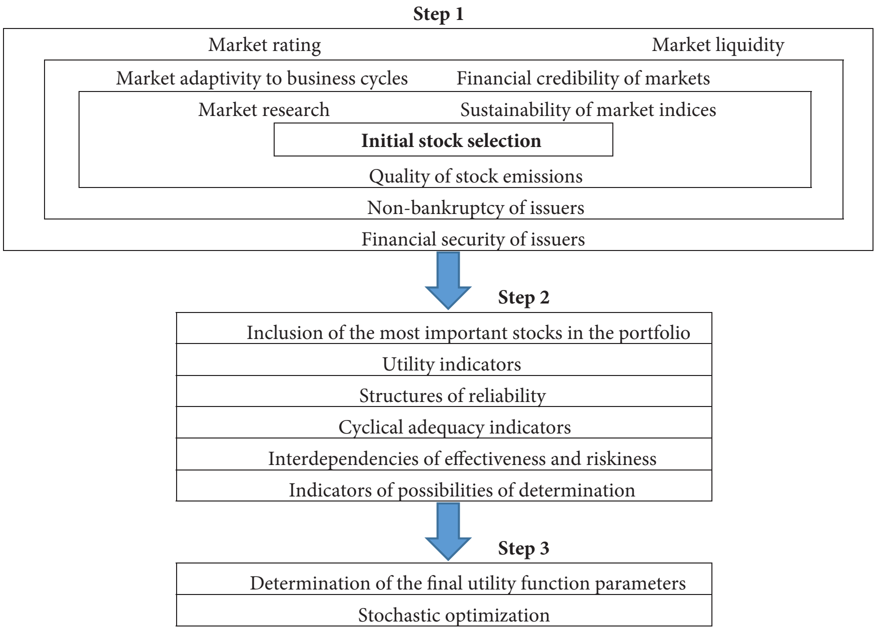


Figure 1. Stochastic structure of the expert system for the selection of markets, issuers and assets

2.2. Realization of the expert assessment

Table 2 presents a brief view explaining how the expert assessment is being performed. 8 characters are distinguished for every asset under assessment. According to the integrated value of these characters that is generated by three experts, its impact for the portfolio functions is determined. The rating given by every expert for any character is given in the form of probability distribution. However, there are some broad constraints regarding the forms and parameters of probability distributions. On the first step, the experts present their ratings for every character assessed. On the second step, the assessments are adjusted with regard to the ratings of other experts. On the third step, the ratings of separate experts for every character are aggregated. On the fourth step, the aggregated ratings are normalized, while on the fifth and six steps the rating of the characters is being performed, where often the most expected value of the character possibility serves as the weight.

Table 2. A scheme of expert assessment

	Characters of assets							
	a1	a2	a3	a4	a5	a6	a7	a8
Experts	Step 1. Ratings of experts for the characters of assets (probability distributions)							
i	4.3477	7.0809	6.7820	1.9026	5.8322	5.4601	3.4994	9.9472
ii	2.6303	5.1055	2.3662	6.6338	0.9977	6.6461	8.4300	6.9858
iii	0.2893	9.0719	1.3379	9.1064	6.3196	9.1018	5.7955	5.5882

End of Table 2

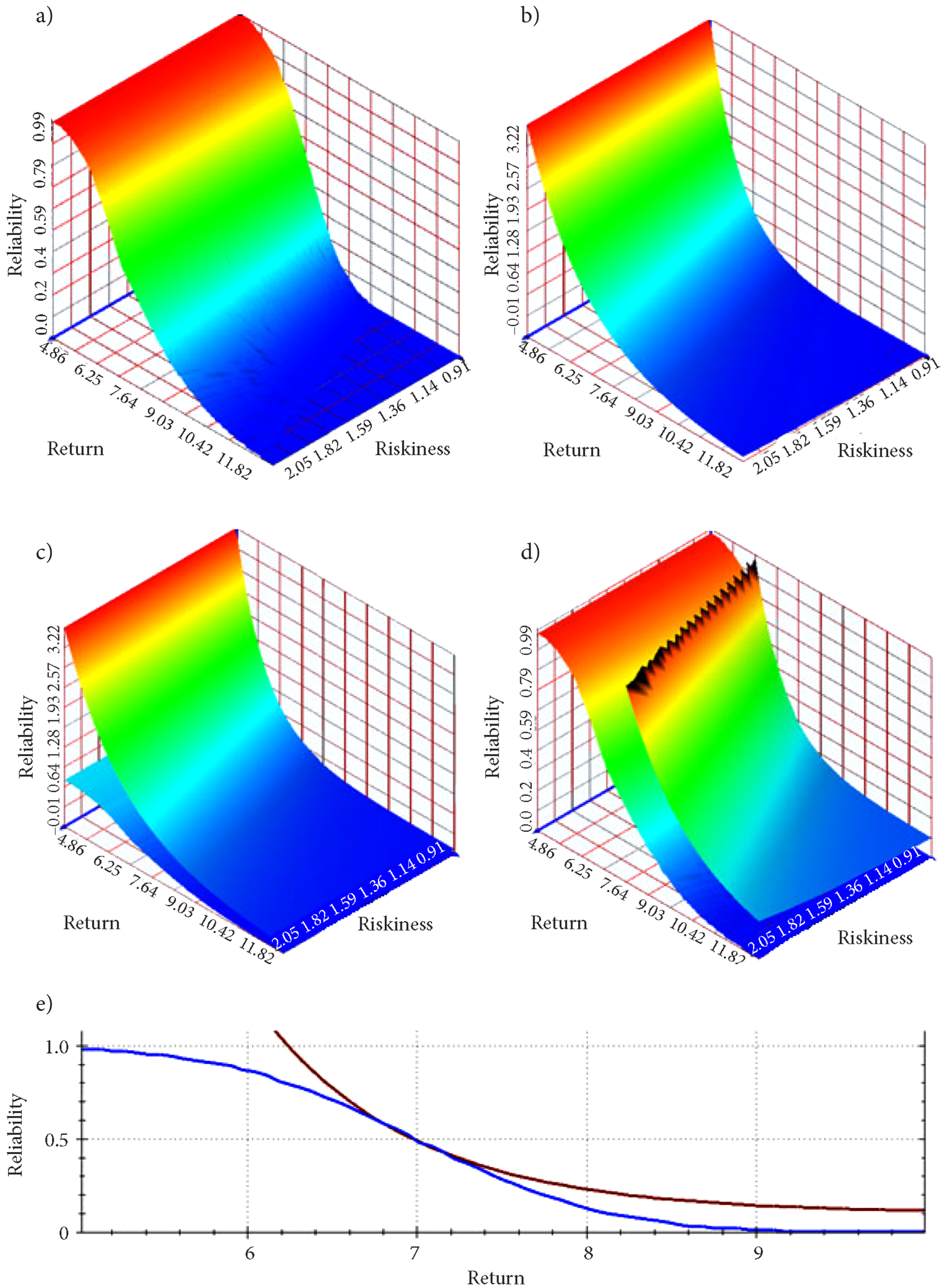
	Characters of assets							
	a1	a2	a3	a4	a5	a6	a7	a8
	Step 2. Adjustment of assessments provided by the experts (with regard to ratings)							
	4.2028	6.8448	6.5560	1.8392	5.6378	5.2781	3.3828	9.6156
	2.5426	4.9353	2.2874	6.4127	0.9645	6.4245	8.1490	6.7529
	0.2797	8.7695	1.2933	8.8028	6.1090	8.7984	5.6023	5.4019
	Step 3. Aggregation of ratings							
	2.3417	6.8499	3.3789	5.6849	4.2371	6.8337	5.7114	7.2568
	Step 4. Normalization of ratings							
	0.0554	0.1620	0.0799	0.1344	0.1002	0.1616	0.1350	0.1716
	Step 5. Determination of the most expected value for the rating possibility							
	0.0554	0.1620	0.0799	0.1344	0.1002	0.1616	0.1350	0.1716
	a1	a2	a3	a4	a5	a6	a7	a8
	Step 6. Rating of characters according to the mode values of the ratings							
	0.0554	0.0799	0.1002	0.1344	0.1350	0.1616	0.1620	0.1716
	a1	a3	a5	a4	a7	a6	a2	a8

Note: Probability distributions in the table are substituted with relative values.

In the example presented in Table 2 we see 3 experts. Such situation is presented for simplicity. In fact, the number of experts depend on the situation and on the number of characteristics assessed. When we analyse the stocks from certain financial index for inclusion in the portfolio, the number of experts typically varies from 5 to 7.

2.3. Detailed scheme to determine the stochastic optimization decision

As it was mentioned in the beginning of the paper, the solution to the formulated problem is perceived as the optimization of the stochastic process. On every step of the process, it is necessary to select the optimal allocation of investment resources among the assets in the portfolio with regard to their most expected return values at the current moment, their reliability and possible riskiness. However, it is important for the portfolio to become a 'synergy forge' where the strong qualities are trained, while the weak ones are eliminated. Selection of portfolio assets out of a vast set of them, as well as constant adjustment of their priority searching for the optimal trend of the process is also oriented towards the achievement of this result. Equally important is that continuous efforts are being made to accumulate the information about the detailed dynamics of the process and to apply it to reach the final goal.



f)

W1	W2	W3	W4	W5	x	P_x	r_x
0.2	0.2	0.2	0.2	0.2	5.11626	0.52	0.90771

Figure 2. A scheme of searching for the stochastically optimal solution

Explanation of Figure 2:

1) Full set of the projected investment portfolio possibilities in the three-dimensional space: 'return possibility, reliability of this possibility, and the riskiness of the environment';
2) A set of values of utility function for the previously determined return possibilities;
3) Equally unambiguous view when a) and b) situations coincide;
4) The view of touch of a) and b) surfaces;
5) Geometrical view of the previously shown touch point;
6) Coordinates and portfolio structure of the touch point.

3. Practical verification of the interaction of stochastically informed expert system and stochastic optimization system

First of all, it is worth noticing that historical data will be used to verify the interaction of indicators. Using these data, possible alternatives of previous development will be searched for, of course, thinking about the possibility to use the obtained information in the future. As the research mainly is related with development resources allocation among the factors influencing development, we will concentrate to a logical experiment. The purpose of the experiment is to determine, whether using the pseudo intelligence emerging in the historical data, one can utilize the evolving situations. In other words, we aim to assess whether the historical data covering the quantitative information about the reliability of return reveals the possibilities for higher return.

Table 3. Illustration of the computer solution search

Step of decision-making	1A	2A	3A	w1	w2	w3	Market-generated value	Backtesting-generated value
1	1	1	1	1	0	0		
2	1.01538	1.07777	1.016947	1	0	0		
3	0.968666	1.024623	1.063558	0.8	0.2	0		
4	1.02065	1.001287	1.003887	0.8	0.2	0		
5	0.996569	0.991524	0.996854	0.8	0.2	0		
6	1.010796	0.994477	0.982401	1	0	0		
7	1.013816	1.012411	1.015567	0.8	0.2	0		
8	1.020689	1.067163	1.011922	0.8	0.2	0	0.9995	1
9	1.05348	0.990703	0.998918	0.8	0.2	0	1.040924	1.040404
10	1.028116	0.990661	1.031893	1	0	0	1.028116	1.069121

Note: The table presents a scheme of 10 conditional steps. The value of portfolio return growth starts being computed from the 8th conditional step. The solutions made before this step are used for internal estimations prepared by the system.

Further we will present our view on final formation and presentation of computer solution. It will be presented using the example of three shares (Table 3).

1. In columns 1A–3A, historical data on stock price growth for the analysed period are presented. The number of steps is explained by the forecasting logics. Currently, 10 steps are analysed. The forecasting method used is moving mode (the amplification of the moving average).
2. In columns W1–W3, starting with the 8th row, the proposed decision algorithm performs the optimal allocation of the possessed investment resource among the separate stocks, on the basis of the previous historical data. According to the proposed solution, the possessed investment resource is relocated, considering the rules and taxes of the stock exchange.
3. In the 8th column the assessment is presented on how our initial sum S0, which equals to 1, should have changed with the emergence of new prices.

In the 9th column we usually see the real return generated by the processed portfolio.

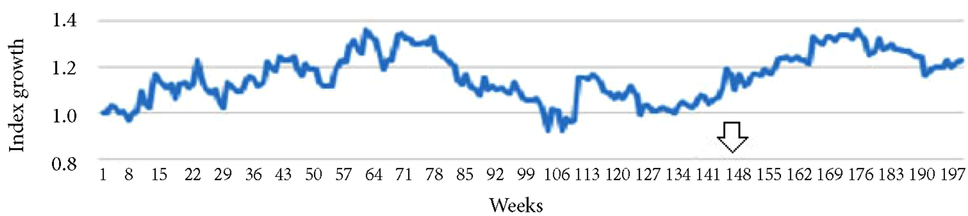
While describing the decision-making process it is worth paying attention that in order to make decision the information presented by the market data is practically sufficient.

4. Visualization of the stochastic interaction of representativeness and optimization

Before presenting visualization it is worth recalling that without adaptive and adequate forecasting system the results would lose their representativeness, while the foreseen goals would lose their relevance. The components describing the market changes should be especially precise and versatile.

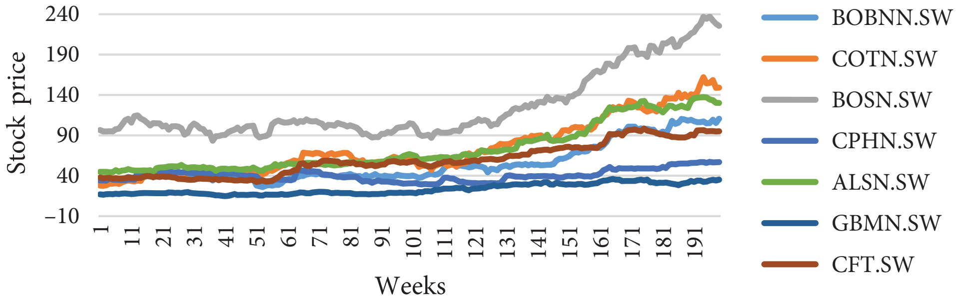
The discussion is initiated with Figure 3, which presents the dynamics of the Swiss Market Index (SMI). Out of this index with the help of our initial selection model 30 shares were selected and would become a means for the realization of our goals. The key components of our goal were: 1) aligning a set of the shares; 2) formation of 3 groups of stocks for the individuals with different risk tolerance; and 3) distinguishing of the group of stocks that could get the attention of only a small number of investors. Implementation of 2nd and 3rd components is revealed in the sections a), b), c), and d) of the Figure 4.

The presented circumstances can be evidenced by the geometrical views, but sections a), b), and c) of Figure 5 also present the quantitative proof.

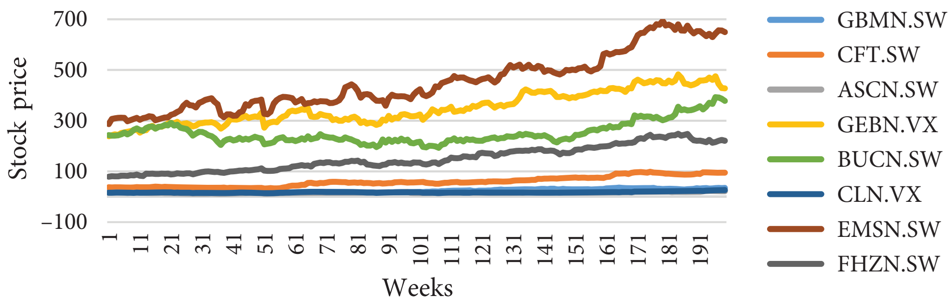


Note: The comparison of assessments provided by the system with historical data starts from 147 week.

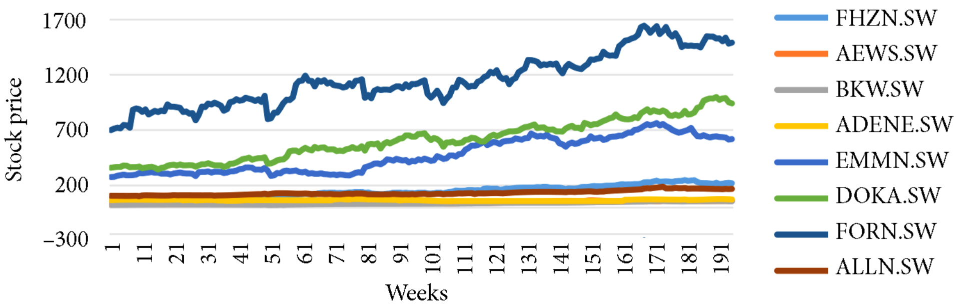
Figure 3. Swiss market index (SMI) value growth historical data for 200 weeks



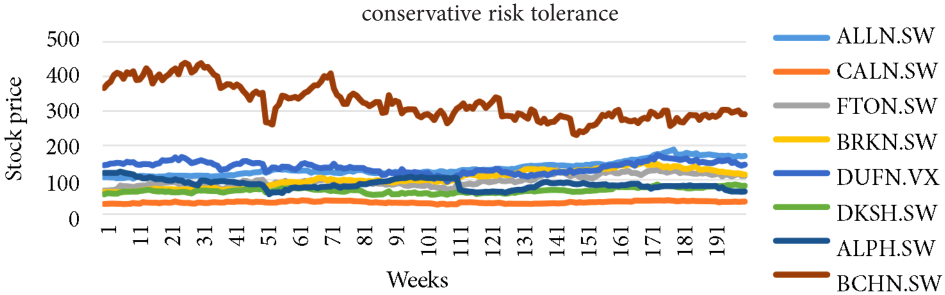
Section a) Shares oriented towards the high level of investment return and high risk tolerance



Section b) Shares oriented towards the moderate level of investment return and moderate risk tolerance



Section c) Shares oriented towards the conservative level of investment return and conservative risk tolerance

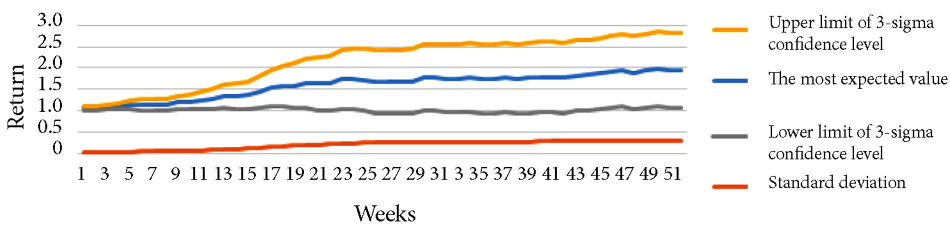


Section d) Shares that can get attention of only a small number of investors

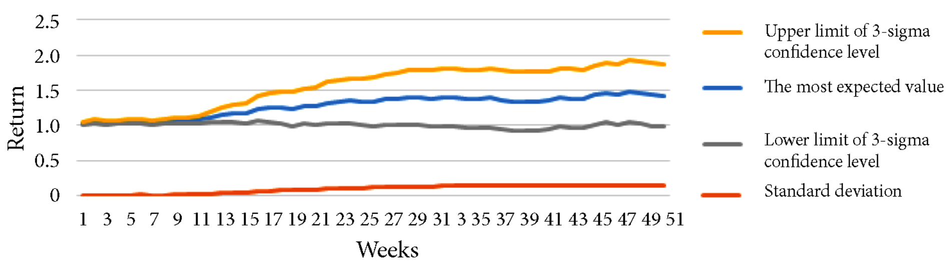
Figure 4. Four groups of shares arranged with the help of the expert system with regard to their adequacy for the goals of portfolio and risk tolerance of potential investors

Figure 4 presents the ranking results that were obtained merely using the stochastically informative expertise. These results attempted to engage the reader in the situation where it is even visually possible to notice the purposefulness of the performed activities. Further we will illustrate the results of our proposed analysis performing the historical data monitoring (i.e. backtesting). These results are obtained applying the optimization system, with the help of market intelligence accumulated in the historical data.

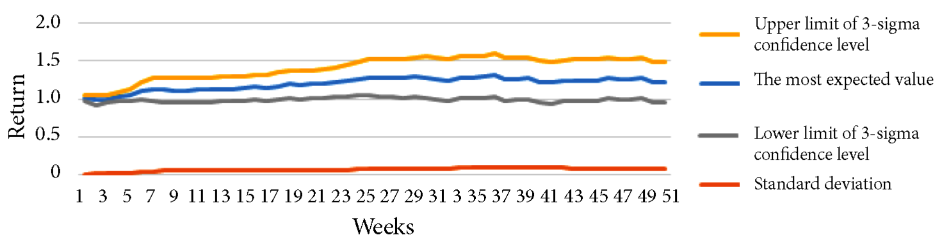
Figure 5 presents the attempt, using stochastically informative expert assessment, to stratify the historical data of the particular market around the investment return dynamics generated by the 30 shares, to prepare them for the stochastic optimization procedure and to assess the obtained results. Quantitative decisions were made using the computer program described earlier in the paper. It was complied with the indicated requirements and the information and logics gathered in the market data has been fully utilized. 3 investment portfolios were constructed and oriented towards the investors having different risk tolerance: A.A. – investors with high risk tolerance; V.A. – investors with moderate risk tolerance, and Z.A. – investors with conservative risk tolerance. The answers of the solutions are presented



Section a) A.A. type (high risk tolerance)



Section b) V.A. type (moderate risk tolerance)



Section c) Z.A. type (conservative risk tolerance)

Figure 5. A search for the efficient investment return possibilities

with the help of the view of 3 sigma confidence zones. In turn, the dimensions of the depicted intervals show that funds invested into the A.A. portfolio could experience a growth of 1.95, A.V. portfolio funds – a growth of 1.42 and A.Z. portfolio funds – a growth of 1.22. Such growth is generated by the weakly increases in every mentioned portfolio. Sections a) to c) of Figure 5 also depict the standard deviation of the forecasted return (the lower curve). This measure represents the accuracy of our forecasting.

Sections a), b), and c) of Figure 5 remind that attempt to compete with the market was performed using 52 out of 200 data weeks, but with regard to information all the data were used. Along with that it is worth paying attention that the presented figures provide sufficient information for the investor on his risk tolerance problems. The confidence intervals of the return generated by the portfolios are depicted. They allow to search for interrelated businesses, activities and ways of living, etc., for the development or existence of which the funds are needed, and, of course, the sources of these funds, for example, financial investment. It is clear that the proposed principle does not represent the full spectrum of possibilities that are available when the investor selects the portfolio structure. However, the universality of the proposed stochastically informed expertise and stochastic optimization principles allows to extend the research of possibilities to the desired level.

5. Analysis of the interaction of portfolio return riskiness and investors' risk tolerance

Three portfolios were presented in the previous section; they have been formed in the selected market with the help of our proposed expert system. Also, their dynamic view is presented having the objective to compare the mutual position of portfolios from different stratas of return-riskiness, as well as to assess their possibilities to implement the goals selected by investor. It is not new that our selected visualization of portfolio return naturally recalls the investment demand for separate business or to perform its certain functions.

As it could be seen from Figure 4 and Figure 5, the behaviour of three successful portfolios in the market has been revealed with the help of stochastically informed expertise. Further attempts to relocate or newly allocate the capital among the selected shares did not give any efficient results. Of course, this is not the notion that an easy way for the investor (for example, investment fund) has been found to form such investment portfolios for all the types of investors that would generate the maximum of the overall investment return. The fact that there is no possibility for any share to participate in several groups is indicated as one of the important observations. However, it is also not a prove that the three-peaks' (forecasting, ranging and optimization) system could not reveal the similar situations in many other markets. If effect, the system could allow to disclose such a commensuration of portfolio return riskiness and investor risk tolerance, which would guarantee that the return of the utilized investment resources approaches the optimal solution. The experiment performed in Swiss stock market – see sections a), b) and c) of Figure 5 – evidences such possibilities.

Before making stratification there is a need for a thorough and reasonable analysis of investor objectives and his risk tolerance. It is important to avoid, to our opinion, quite often mistakes, when one decides to use the possibilities of the subject having higher risk

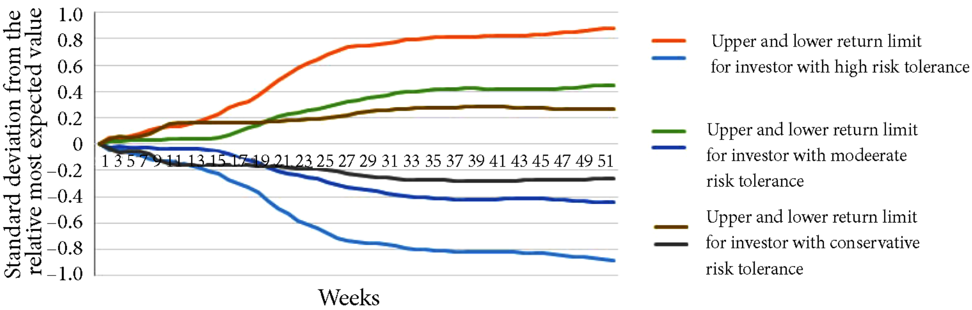


Figure 6. The hierarchy of return for the investors having different risk tolerance level

tolerance. It could be clear from Figure 6, which was obtained by transformation of sections a), b), and c) of Figure 4. Let us analyse the investor having the lowest risk tolerance. The return generated by his portfolio is covered by the internal interval. But he can be offered to orient towards the higher return possibilities. However, we should take into account that the return-generating portfolio can also generate return that is lower than the lowest line of the confidence interval under analysis. This, in turn, would provide huge loss for the specified investor.

Let this be a final argument enabling us to recall that the transformation of the analysed events and processes usually has some possibilities having certain reliability. Reliability of the result transformation often can be the main information indicating for what possibility of event transformation one should prepare. We should estimate and assess the reliability of possibility transformation especially responsibly. Its value can be high enough.

6. Portfolio of the interaction of macroeconomic indicators

The abundance of the complex investment portfolio decisions was determined by the huge attention to the adequate combination of means and methods, as well as by the creation of adaptive instruments for the needs of investors. Additional attention has been always given to the proper identification of problems being formed in the markets. Also, one should also consider that the activity determining the portfolio as an interaction of assets was the summation of these assets. Along with that, often the assumption is being made about the possibility to treat the assets as determinated variables.

Analytical formulation of the problems, as well as identification of their decision means becomes more complicated if the summation as an expression of portfolio assets' interaction is being changed. It can be changed by the function of complex stochastic interaction of these assets. Also a big challenge is the necessity to quantitatively assess on every step the reliability of every function and possibilities of transformation of factors. In turn, while analyzing the management of social and economic problems, one should constantly take into account the possible contradiction of our objectives with existing viable powers of markets and disposable resources.

Further we can try to re-orient towards the situation where the definition of investment portfolio used in the previous part of the text has declared portfolio as a sum of investment assets. Now this definition is augmented to the status of the complex stochastic function, and the analysed investment assets receive the role of factors (that in turn can become the objective functions). It is worth noticing that the presented explanation particularly expresses intention to further analyse the investment portfolio perceived as an optimal allocation of various development resources. Such concept has already been expressed in the title of the paper, along with the objective of the paper, namely: stochastically informative expertize and optimization for investment.

The possibilities of the new investment portfolio function can be revealed not only by forming portfolios in the financial markets. We can select the traditional problem, already investigated by many analysts and practitioners. The question is posed whether it is possible, using four factors significantly influencing the country economic efficiency, and applying the smart management, to determine the dynamics of GDP – the integral indicator of country economic power? The four indicators are: 1) wages and salaries; 2) production capital; 3) employees; 4) investment. There is no doubt that in order to reach reliability, more factors are required, along with the broader concept of country economic development. However, the obtained result should inform the readers about certain possibilities of the proposed principle.

Historical data of the three countries are used for the experiment, considering that these countries are rather versatile in terms of their level of economic power and structure. The data analysed includes GDP, wages and salaries, production capital, employees, investment. The countries under analysis are Lithuania, UK and USA. The data for UK is presented in Table 4. The geometrical views of solutions are presented in sections a), b), and c) of Figure 7.

Table 4. Macroeconomic indicators. UK historical data

Years	GDP	Wages and salaries	Production capital	Employees	Investment
1995	39548.55	15777.11	7165.53	25814.34	7245.29
1996	42586.52	16608.35	7947.86	26056.25	8036.08
1997	51643.13	20623.98	8984.77	26522.79	9140.83
1998	54587.06	22610.25	9746.99	26793.53	9934.84
1999	57527.92	24367.62	10266.74	27167.08	10475.83
2000	65020.75	27830.85	11599.58	27483.29	11814.27
2001	65367.07	28916.99	11278.79	27711.39	11622.27
2002	67145.72	29186.84	11629.38	27943.90	11978.80
2003	63927.89	27284.68	10761.04	28223.07	11053.13
2004	67654.23	28899.57	11313.07	28533.45	11629.76
2005	70268.68	29344.62	11914.98	28853.15	12219.72
2006	73665.61	30871.11	12644.07	29140.45	12965.15
2007	76426.81	32294.02	13498.10	29378.75	13795.04
2008	66653.02	28110.79	11317.35	29627.56	11550.97
2009	58885.62	25557.45	8985.48	29154.26	9168.49
2010	63013.65	26823.89	9659.63	29226.87	9842.73

End of Table 4

Years	GDP	Wages and salaries	Production capital	Employees	Investment
2011	64136.06	26779.81	9861.71	29374.62	10050.12
2012	69989.07	28905.07	10915.18	29694.53	11149.26
2013	68690.82	28367.95	10865.12	30042.22	11066.09
2014	74104.57	30138.52	12140.52	30752.41	12301.36
2015	83185.55	34147.73	13793.77	31281.15	14083.31
2016	75516.83	30916.53	12453.15	31725.39	12581.10
2017	72501.89	29613.74	12225.71	32058.38	11939.96

Notes:
1) GDP, wages and salaries, production capital and investment is expressed in thousand EUR per employed persons per year;
2) Employees are expressed in thousand.

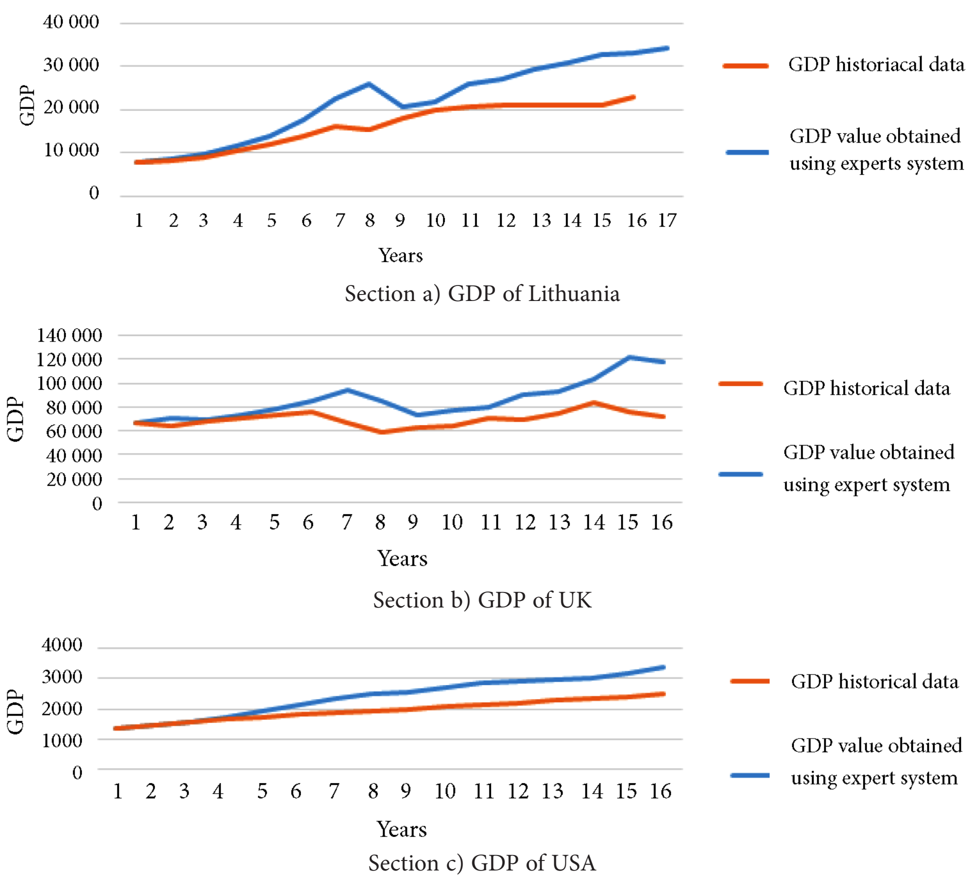


Figure 7. Comparison of historical GDP and GDP value proposed by the expert system

In order to reach decision, historical data testing and forecasting methods have been used. The decision-making comprised of the following steps:

1. The first seven rows of the presented indicators received the status of integrity;
2. For the indicators in 8 to 23 rows the moving most expected values were generated;
3. The forecasted 24th indicator also was generated the analogous value.

Note: For 11 to 23 GDP values the moving most expected value has been generated using LINEST (LOGEST) functions, along with that solving the task of stochastically optimal development resources utilization.

Conclusions

1. The systems of stochastically informed expertize and stochastic optimization were developed by the authors and presented in the paper. They allow to analyse constructively the behaviour of financial markets, forecasting the dynamics of stock prices and along with that rationally allocating investment resources in the course of market functioning. For the mentioned analysis, forecasting and problem solving by the selected stochastic model of financial market behaviour, as well as stochastic manner for decision selection and development of optimization strategy has been applied. The key provision of these instruments is the quantitative assessment of the analysed possibilities' reliability and adequate utilization of this ratio to make decisions.
2. Exceptional attention should be paid to the interrelated stratification of the riskiness of portfolio return and investors' risk tolerance. Holistic balancing of the riskiness of return and investor's risk tolerance is treated as a means that can substantially increase the market-generated return for the particular macro-subject.
3. The provision of the strategic trend of development of the knowledge system for the investment in financial markets becomes the fact that key portfolio function should be not only the management of the sum of returns generated by the portfolio assets. Portfolio thinking must also form the cognition and management of complex stochastic functions that accumulate objective interaction of a set of multidimensional factors.
4. Along with financial investment portfolio, the paper presents and approves the model of portfolio of macroeconomic indicators' interaction. It has been built on the basis of historical data from the countries of rather different level of economic development. This model evidences the capability for the investment portfolio to accept the function to analyse the possibilities of complex stochastic system development, as well as to create the constructive development strategies. Such function also smartly covers the possibilities of stochastic optimization and stochastically informed expertize.
5. The interaction of the formulated theses with the facts revealing the market transformation, as well as grounding the forecasted consistent patterns with the actual behavior of the historical data could only be possible using historical data possessing the market intelligence. Also, the work of a group of researchers that form the market

pseudo-intelligence using the mentioned elements of intelligence is of great value. The use of artificial intelligence to form the intelligent investment strategies should become a factor of success for the investment in financial markets.

6. Great attention should be paid to the portfolio of macroeconomic indicators' interaction. The instruments of stochastic expertize and principles of stochastic optimization have been used. Also, general principles of investment portfolio management and intelligence gathered in the historical data of the markets has been applied. The management possibilities of country key social, economic and technological indicators' interaction has been revealed in order to reach the stochastically optimal growth of the main indicator describing the socio-economic maturity of the country.
7. The performed research is not without limitations. The analysed Swiss stock market is only the part of possible analysis, so further studies can be useful to test the expert system in other developed and developing stock markets. Regarding the experiment with macroeconomic data, the research has been performed with USA, UK and Lithuanian historical data. Also, more countries from different regions would present the broader picture of applicability of the system.

Disclosure statement

The authors declare no conflict of interest.

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