R E V I E W

over dissertation work for the acquisition of educational and scientific degree "doctor" in the professional field 4.6. Informatics and computer science, scientific specialty "Informatics"

Author of the Ph.D. thesis: VESELIN LASAROV SHAHPAZOV

Topic of dissertation work: Investigation of models for forecasting capital markets with neural networks

Reviewer: Prof. D.Sc. Eng. Chavdar Ivanov Damyanov

Materials received: Dissertation, autoreferat, document folder and copies of dissertation publications.

This review has been prepared in accordance with the decision of the Scientific Jury appointed by Order No: 262 / 31.10.2019 of the Director of IICT, BAS-Sofia, since its meeting on 04.11.2019.

The dissertation is developed mainly at the Institute of Information and Communication Technologies at the Bulgarian Academy of Sciences (IICT - BAS). It is formed on 148 pages (A4 format) standard computer typed text containing 12 tables, 21 figures, Introduction - 5 pages, Eight chapters (Chapter 1. Capital Market Forecasting Models - 24 pages; Chapter 2 - Analysis of Neural Network Methods for Capital Market Forecasting - 49 pp. Chapter 3 - Results from the Study of Neural Network Capital Market Forecasting Models and the Development of a Hybrid Model of Neural Networks and Systems Based on Capital Market Forecasting Rules - 45 pages; Chapter 4 - Guidelines for Being and Research - 1 p. Chapter 5 - Conclusion - Summary of the results - 6 pp.). The dissertation cited chapters 6, 7 and 8 as separate and separate: publications on the topic of the dissertation, participation in projects and a bibliography, which is practically not done.

The submitted materials and documents meet the requirements and are in accordance with the Law on Higher Education (ZVO), the Law on the Development of the Academic Staff in the Republic of Bulgaria (ZRASRB), the Regulations for the implementation of the Law on the Development of the Academic Staff in the Republic of Bulgaria (PPZRASRB) and The Rules for the Terms and Conditions for the Acquisition of the Doctor Scientific Degree in BAS, Sofia.

1. The urgency of the problem, developed in the dissertation, in scientific and applied scientific terms. Degree and levels of relevance of the problem and the specific tasks developed in the thesis.

The dissertation is in a topical and important scientific and applied field. Undoubtedly, the study of capital market forecasting models has a direct economic sense and their effective application is a topical topic, which has recently become especially relevant in Bulgaria, as part of the formation of our sustainable market environment within the European Community.

The strong development of computer science and information technology has made it possible to apply new methods of analysis and synthesis of complex algorithms for managing objects, processes and environments, which until recently were unavailable by conventional means. The latter should include the search for new formal methodologies for modeling and forecasting capital markets with artificial intelligence elements. Most exchanges, banks and hedge funds have systems that predict future market movements through probabilistic-statistical and regression models, but artificial intelligence is not yet the dominant force in the markets. However, this will soon change.

It is now being observed that the capital market is gradually realizing that artificial intelligence (AI) has huge business potential. It will allow rapid response to data forecasting, increase quality and give a better interpretation of workflows, data and customers. Like any other industry, financial markets are profit-oriented and are constantly looking for business strategies

to get one. Realizing that there is a lot of potential in implementing AI, they turn to it. Artificial intelligence is expected to reduce the risks of cyberattacks and to make the financial sector more efficient by eliminating human intervention. It is argued that AI will certainly change the well-known financial industry.

The reason why artificial intelligence is perfectly suited to the financial market can be found in the vast amount of data that is processed and stored in the sector on a daily basis. All this information has not only application data, but also counterparty data. In addition, user actions are recorded, for example, what is considered a regular situation, or what is an exception and that required intervention. There is also data on customer behavior over the years. And all this is what AI needs, since machine learning requires a lot of data to function efficiently.

The relevance and importance of a thesis work depend on the set goals and objectives. To the extent that the purpose of the dissertation is to enrich contemporary knowledge in a specific scientific field, which is achieved through adequately assigned and fulfilled tasks, then its relevance should be a logical consequence of this.

In view of the above, I definitely think that the dissertation presented on "Investigation of models for forecasting capital markets with neural networks" is not only up-to-date, but I would also say that it also opens up new horizons for research in this highly promising area of forecasting the financial markets. In this sense, I find the goal of the dissertation, also defined in the title "Investigation of models for forecasting the capital market with neural networks", to be definitely relevant and important for the analysis of the capital market. The results of the studies presented therein would have a definite contribution, both scientifically and applied character.

In this case, a certain novelty is the proposed appropriate artificial neural network structure for achieving better quality of forecasting on a low liquid financial market, such as the Bulgarian one. capital market, with appropriate selection of the input parameters for the forecast model selected so that it can make accurate forecasts.

I accept that the statement, the purpose and the accepted tasks in the submitted dissertation determine its relevance.

2. Degree of knowledge of the problem state and creative interpretation of the literary material.

In the development of his dissertation, the author has used 139 literary and electronic sources. The sources used are mostly in Latin (only 3 are in Cyrillic - [113 ÷ 115]). Most of them have been published after 2000 and reflect the current state of the thesis. Most of them are directly related to the topic of the dissertation and illustrate good knowledge, thorough knowledge of the problem and competence of the doctoral student.

The bibliography also includes publications on dissertation work.

I believe that Veselin Shahpazov is thoroughly aware of the problem, which is related and due to his direct professional duties. The dissertation creatively evaluated and interpreted the literary and reference material.

3. The correspondence of the chosen research methodology and the stated purpose and tasks of the dissertation with the contributions made.

The purpose of the thesis of Veselin Shahpazov is to offer effective working models for capital market forecasting with artificial neural networks

Six objectives have been formulated to achieve this goal:

- Investigation of the formation, development and ability of neural networks to forecast the capital market.
- Analysis of methods for forecasting capital markets with neural networks.
- Research on the Bulgarian stock market as a subject of forecasting.

- Formation of a hybrid model for capital market forecasting.
- Conducting experiments with the hybrid model in the real conditions on the Bulgarian capital market.
- Summary of results achieved and future development of the model.

The dissertation is methodologically correctly chosen first to systematize the tasks required for the performance, and these tasks are consistently elaborated in the relevant chapters of the dissertation.

The subject of research in the dissertation is the prediction of the BG40 and Sofix stock exchanges on the Bulgarian Stock Exchange (BSE).

Familiarity with the content of the dissertation, the created methodologies and models, the analyzes and simulation studies conducted, conclude that the chosen research methodologies are in direct accordance with the stated purpose and tasks of the dissertation. The simulation studies were performed in the middle of the STATISTICA 7 Neural Networks software package.

It should be noted that the results obtained confirm the validity of the selected study methodologies.

4. Brief analytical characteristics of the nature and evaluation of the reliability of the material on which the contributions of the dissertation are built.

The doctoral student has a thorough knowledge of the dissertation and has demonstrated his accumulated experience and knowledge in the creation of models and projects possessing intrinsic complexity and multidimensionality of the proposed solutions.

I did not notice in Veselin Shahpazov's dissertation the formulations and methodologies that cast doubt on the final conclusions. I accept that the yields for which he claims are his own business.

The dissertation has presented part of its results in scientific forums or published in specialized publications, which is also a guarantee of their accuracy. Veselin Shahpazov has participated in 2 research projects, but the materials lack official information from the relevant organizations about his participation in the submitted scientific projects.

The overall analysis of Veselin Shahpazov's dissertation gives me reason to believe that the reliability of the contributions of the dissertation is undoubted and definitely his personal matter.

5. Scientific and / or applied scientific contributions to the dissertation

The thesis of Veselin Shahpazov is based both on known standards, structures and methodologies, as well as on reasonably modified and further developed models, methods and their implementing software, which led to the creation of a methodology for exploring the possibilities for forecasting capital markets with neural networks. In accordance with the requirements of the ZRASRB, the applicant must have a thorough theoretical knowledge of the relevant specialty and the capacity for independent scientific research. I believe that the submitted dissertation and publications meet the requirements of the Law.

I accept as justified contribution claims in the form edited by Veselin Shahpazov, and I consider that in their form they correspond to the results obtained by him. A refinement of the contributions would lead to their generalization in terms of the models and methodologies created. As presented, they represent an extended summary of the results of the studies carried out.

In summary, I find the following scientific contributions:

• The formation, development and ability of neural networks to forecast the capital market is analyzed;

• A range of neural network models for prediction of the main stock indices on the Bulgarian stock market has been proposed and experimentally tested;

- A hybrid model of neural networks and systems based on rules for forecasting underdeveloped and low liquid capital markets, such as the one in Bulgaria, has been proposed.

The doctoral student has worked for a long time on the subject of his dissertation, has conducted in-depth research, received, presented and analyzed many results. He made the relevant conclusions, which gives me reason to believe that the presented work has the necessary scientific and applied contributions.

6. Assessment of the degree of the dissertation's personal participation in the contributions.

I think that the degree of personal participation of the dissertation student in the contributions is very high, naturally considering the support and assistance of his scientific advisor - Academician Ivan Popchev. The scientific contributions received in the dissertation related to the creation of new models and methodologies for forecasting capital markets based on neural networks are a serious creative achievement.

The presented dissertation, abstract and publications give sufficient grounds to consider that the work on the dissertation work and the obtained results are a personal matter of Veselin Shahpazov.

7. Evaluation of dissertation publications.

The results of Veselin Shahpazov's dissertation are reflected in six publications, one of which is an article, three were presented at international symposia abroad - the Netherlands, Luxembourg, Poland (2013 and 2014) and two at conferences with international participation in Bulgaria (Bankya and Plovdiv). The article is in Bulgarian language and is independent. The other publications are in English and co-authored, with V. Shahpazov being the first author.

It should be noted that the publication in Poland (*Shahpazov V., V. Velev, L. Doukovska - Design and Application of Artificial Neural Networks for Predicting the Values of Indexes on the Bulgarian Stock Market, Proc. Of the Signal Processing Symposium - SPS '13, Jachranka Village, Poland, CD, ISBN 978-1-4673-6319-8-13- 2013 IEEE, 2013*) has 6 citations abroad.

In summary, Veselin Shahpazov's scientific-metric indicators meet and exceed the minimum requirements of the ZRASRB, the Rules for its implementation, as well as the specific requirements of IICT-BAS.

I accept that the dissertation publications reflect major parts of the development and that its results are known to the scientific community working in the field of the specialty.

8. Use of the results of the dissertation work in scientific and social practice.

The dissertation has both theoretical experimental and applied implementation character, with a specific focus on the creation of neural network models, used to predict the future development of the main indicators on the basis of which the classification of emissions from the BSE index of Sofix is made.

In this sense, the proposed methodologies and the results obtained have a real chance of being used in fintech and business practice, as well as for the training of the respective staff, which makes them useful and relevant for scientific and social practice.

9. Assessment of the correspondence of the autoreferat with the requirements for its preparation, as well as the adequacy of reflecting the basic positions and contributions of the dissertation.

The presented project for the autoreferat of the dissertation and the dissertation work of Veselin Shahpazov give me reason to conclude that the autoreferat t is in line with the dissertation and reflects its basic positions and contributions.

The autoreferat is written in clear and stylish language, according to the requirements and as a content (35 pages) accurately and correctly reflects the results and achievements in the dissertation.

10. Opinions, recommendations and notes.

My personal impressions of Veselin Shahpazov are mostly based on his scientific output. As an external reviewer I have no direct impressions of his work and his research activity, but from the presented dissertation, obtained results and achievements, it appears that Veselin Shahpazov is a well-prepared and actively working researcher, therefore my personal impressions about him are completely positive.

I have no critical material remarks regarding gross inaccuracies, incorrect conclusions. I will note only the following:

• Pursuant to the PPZRASRB Art. 27.(1): The dissertation work must contain: title page, content, introduction, statement, conclusion - summary of the obtained results with a declaration of originality, which is unconditionally observed by the doctoral student. But there are also unwritten rules regarding content structuring, which are that after the introduction, which discusses the relevance of the defined dissertation topic, the first chapter gives an overview of the current state of affairs and, on the basis of critical analysis, the purpose and necessary tasks are formed for its achievement. In this case, there is a non-standard approach, the purpose and objectives of which are presented in the introduction, and the first chapter is mainly devoted to an overview of known methodologies relevant to capital market forecasting.

• Excessive affinity for detailed descriptions of known productions, accompanied by an interpretation of their individual details, is manifest, which is atypical for dissertation work (item 1.3, item 2.1 ÷ item 2.6).

• In theses with similar thematic focus, the practice of using graphical interpretations with block diagrams, diagrams and other illustrations of text and simulation experiments is well established. In this respect, the work of the doctoral student is poorly informative.

• It would be good to comment on what procedures are used to assess the degree of risk involved in decision-making. There is an ongoing debate in the financial sector about interpreting AI results, since most AI methods are like a black box. So are neural networks. They give end results but do not explain why and how they received this answer. For example, in banking environments it is considered extremely dangerous. In this sector, it is simply unacceptable to allow robots to make certain decisions without providing an adequate and plausible explanation for their behavior. In this sense, developers need to be especially careful about applying the right technology to a particular problem, especially in a highly volatile market.

• The working capacity and reliability of the developed models and methodologies is proved on the basis of working with real data in real (field) conditions. Of particular interest is the proposed hybrid model of neural networks and systems based on capital market forecasting rules, but it is proposed in the conceptual phase, without testing how simulation studies would show better accuracy of estimates when compared to real data.

As a general note, I would like to mention some of them of a terminological nature; lack of a list of abbreviations and abbreviations used in the thesis; fixed typographic and spelling errors, etc.

The above critical remarks do not detract from my positive assessment of the thesis. They are advisable and do not affect the overall good impression that the applicant's production produces.

Given the relevance of the dissertation I recommend Veselin Shahpazov to publish publications in reputable international journals, which would provide better visibility of the obtained results, and the corresponding citation index will be an international attestation for his work.

Conclusion

I believe that the dissertation fulfills the criteria for acquiring the scientific and educational degree "doctor", enshrined in the Law for the development of the academic staff of the Republic of Bulgaria and the Rules for the conditions and procedure for acquiring the educational and scientific degree "doctor" in IICT - BAS. From the above, I remain convinced that the presented development is up-to-date and with its usefulness and applicability the results have led to the successful completion of the tasks set in accordance with the purpose of the dissertation. The models developed are original solutions and confirm the PhD student's readiness for independent research.

I give a positive assessment of this dissertation work and I will vote for VESELIN LAZAROV SHAHPAZOV to give the educational and scientific degree "Doctor" in professional field 4.6. Informatics and computer science, scientific specialty "Informatics".

11/30/2019

REVIEWER:

(Prof. Chavdar Damyanov)