

OPINION

by **Prof. Dr. Hristo Stefanov Kiskinov, PhD,**
Professor at Plovdiv University "Paisii Hilendarski" (PU),
Faculty of Mathematics and Informatics

of a dissertation for the award of the educational and scientific degree "**Doctor" (PhD)**
by: Area of Higher Education 4. *Natural Sciences, Mathematics and Informatics*;
Professional Field 4.5. *Mathematics*;
Doctoral Program *Mathematical Modeling and Application of Mathematics*.

Author: Ivaylo Vladimirov Boyoukliev.

Title: "Modeling and Research of Foreign Exchange Financial Markets"

Scientific Supervisors: Prof. D.Sc. Snezhana Georgieva Gocheva-Ilieva and Associate Prof. Dr. Hristina Nikolova Kulina

1. General Presentation of the Procedure and the PhD Student

By order No. PD-21-238 from 29.01.2024 of the Rector of the Plovdiv University "Paisiy Hilendarski" (PU), I have been appointed as a member of the scientific jury to ensure a procedure for the defense of a dissertation (PhD-thesis) titled "Modeling and Research of Foreign Exchange Financial Markets" for awarding the educational and scientific degree "doctor" in the area of higher education 4. *Natural sciences, mathematics and informatics*, professional field 4.5 *Mathematics*, doctoral program *Mathematical Modeling and Application of Mathematics*. The author of the dissertation is Ivaylo Vladimirov Boyoukliev - full-time PhD student at the Mathematical Analysis Department of the Faculty of Mathematics and Informatics (FMI) at Plovdiv University Paisiy Hilendarski with scientific supervisors Prof. D.Sc. Snezhana Georgieva Gocheva-Ilieva and Associate Prof. Dr. Hristina Nikolova Kulina.

The set of paper and electronic materials presented by the PhD student Plamena Ivanova Marcheva is in full compliance with Article 36 (4) of the Regulations for the Development of the Academic Staff of the PU and includes all the necessary documents.

Ivaylo Vladimirov Boyoukliev was born on 13.11.1969. In 1993, he obtained the Master's degree at UNSS – Sofia in "Accounting and Control". Since 2020, he has been a full-time PhD student at the Department of Mathematical Analysis at the FMI at the PU. From 1994 until now, he has worked in various positions in several banks, constantly rising in the hierarchy (dealer, senior dealer, head of department, director of directorate).

2. Actuality of the Research Topic

The use of powerful methods of mathematical modeling in economics, and in particular in the study and forecasting of the dynamics of foreign exchange financial markets, is an evergreen topic. It is particularly relevant in today's globalized world, which is easily established by following the publication activity of those working on this topic in specialized journals.

3. Knowing the Problem

The carried out review of scientific research on the problem, the selected literature and above all the obtained results speak unequivocally of deep knowledge in the researched field.

4. Research Methodology

The research methodology is standard for mathematical modeling and application of mathematics – introduction of new methods and approaches, construction of relevant models based on them, testing them with real data and analyzing the obtained results.

5. Characterization and Evaluation of the Dissertation Work and Contributions - Presence/Absence of Plagiarism

The PhD-thesis "Modelling and Research of Foreign Exchange Financial Markets" is dedicated to the modeling and research of dependencies in various data sets from the field of foreign exchange financial markets by using means of statistical modeling, methods and algorithms for time series analysis. It is written in 160 pages and consists of an introduction, four chapters, a conclusion and a bibliography with 135 titles. The presentation also includes a useful list of used symbols and abbreviations, 46 tables and 68 figures. The first chapter has an overview character and presents the main elements and stages of statistical modeling, the applied field, a literature review on the topic of the dissertation, the methods used and the goals and tasks of the research are formulated. Chapters 2, 3 and 4 describe the conducted research and analysis, and the main obtained scientific and scientific-applied results. In the conclusion, the doctoral student made a self-assessment of the contributions contained in the dissertation and described the approbation of the obtained results.

I support the main contributions described by the PhD student in the current dissertation. Namely:

- A general research framework for statistical modeling of univariate and multivariate time series in the field of currency and financial markets has been developed and applied. The framework includes a predictor identification approach and the application of understudied intelligent machine learning methods for forecasting and short-term forecasting.

- Effective predictive models of one-dimensional time series for foreign currency deposits of Bulgarian citizens have been built and analyzed. For this purpose, the CART Ensembles and Bagging (EBag) ensemble method has been applied and studied for the first time in this field. The models without data transformation were found to be more accurate and reach a match with the real values up to 97.7%. The models have been applied to obtain forecasts for deposits 3 months ahead and show significantly better results than the reference ARIMA model.

- Highly efficient multivariate time series forecasting models for the EUR/USD exchange rate depending on macroeconomic factors were built and analyzed using three methods - EBag, Arcing and Random Forests. For the first time in the field of financial and currency markets, the Arcing ensemble method of the gradient amplification class has been applied and studied. The influence of individual macroeconomic factors on the exchange rate has been determined. The obtained modeling results show an accuracy advantage of the Arcing models with a mean absolute percentage error (MAPE) equal to 1% and reaching a data match of up to 99.1%. The one-month-ahead forecasts for all three methods are comparable to the accuracy of the observations.

- An approach for hybrid Arcing-ARIMA modeling of data for deposits of Bulgarian citizens with transformed and untransformed data was developed and implemented. The resulting hybrid models with untransformed data were found to be more accurate and achieve statistical indicators MAPE=12.9%, matching data up to 99.6%, and most accurate forecasts for the three test "future" months not included in the modeling. These results have been shown to outperform the predictive capabilities of standard ARIMA and Random Forests methods.

I do not detect "plagiarism" in the works of the author and the presented thesis in the sense of the Law on the Development of the Academic Staff in the Republic of Bulgaria.

6. Assessment of the Dissertation's Publications and Personal Contributions of the Author

The presented dissertation is based on 4 publications in English, of which 2 in journals and 2 in conference proceedings. One of the articles is in a journal with an impact factor of IF=1.2 and Q3, three are indexed in SCOPUS, two have SJR=0.164 and SJR=0.464 respectively, and one is indexed in ACM Digital Library. They form a total of 93 points, which exceeds more as three times the minimum national criteria for this indicator, requiring 30 points. All 4 presented articles are co-authored by some of the two scientific supervisors. For me, the candidate's personal contribution to them is undoubted.

I have no major criticisms.

7. Summary

The Summaries, written in Bulgarian and in English, have 32 pages, correspond to the requirements of RDASPU and contain the main results obtained in the dissertation work.

8. Recommendations for Future Use of Dissertation Contributions and Results

I wish the PhD student to continue working in this interesting field and with the same enthusiasm.

CONCLUSION

The dissertation *contains scientific, scientific-applied and applied results, which are an original contribution to the science* and **meet all the requirements** of the Law on the Development of the Academic Staff in the Republic of Bulgaria (LDASRB), the Regulations for the Implementation of the LDASRB and the relevant Regulations of Plovdiv University "Paisii Hilendarski". I detect no plagiarism. The presented materials and dissertation results far exceed the minimum national requirements introduced by the Regulations for the Implementation of the LDASRB.

The dissertation work shows that the PhD student Ivaylo Vladimirov Boyoukliev possesses in-depth theoretical knowledge and professional skills in the scientific specialty Mathematical Modeling and Application of Mathematics, demonstrating qualities and skills for conducting research with obtaining original and significant scientific contributions.

Due to the above, I confidently give my **positive assessment** of the conducted research, presented by the above-reviewed PhD thesis, summary, achieved results and contributions, and ***I propose to the honorable scientific jury to award the educational and scientific degree "Doctor" (PhD)*** to Ivaylo Vladimirov Boyoukliev in the Area of Higher Education 4. *Natural sciences, Mathematics and Informatics*; Professional Field 4.5. *Mathematics*; Doctoral Program *Mathematical Modeling and Application of Mathematics*.

22.03.2024

Plovdiv

Scientific jury member:

Prof. Dr. Hristo Stefanov Kiskinov