

Review of Doctoral Thesis

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Title: Modeling and research of foreign Exchange Financial markets
Reviewer: Prof. Leda Minkova, PhD, DSI

Ivaylo Boyokliev graduated in bachelor program of Accountancy and control in the University of National and World Economy in 1993. Since 2020 he is a doctoral student in Plovdiv University. At the same time he works in a bank on the financial risk control.

General description. The thesis consists of Introduction, four chapters, conclusion, and a References, written on 160 pages. The references contain 135 titles. The thesis is presented for acquiring the educational and scientific degree "Doctor" in 4.Natural Sciences, Mathematics and Informatics, PhD study program Mathematical Modeling and Application of Mathematics in Plovdiv University.

In **Chapter 1** a literature review is given. With many and correct citations, the author explains the main directions of the statistical modeling with application in financial markets. The models and methods are explained in detail. The author compares the models. The software is indicated.

In **Chapter 2**, a new approach for modeling and forecasting the time series is presented. The analyzed data are for the short-term deposits of Bulgarian citizens in ASD currency. The data are taken from the Bulgarian National Bank. The models are applied to the initial data, and then to pre-transformed data. The transformation of the data is applied to improve the distribution close to normality. The results of the transformation are given in many tables and figures. . The author uses methods, which are independent of the distribution and predict well the extreme values. On the transformed data the ARIMA model is applied (see 2.3.2). The author compare the results in both cases. (Figure 2.9).

In **Chapter 3**, a short-term forecasting of the dynamics of the EUR/ASD exchange rate is analyzed. The exchange rate is considered as a function of the main macroeconomic factors. ARIMA model is applied to the data. Then, the results are compare by three methods with mashine learning. The data are taken from Bloomberg for a period of 227 months. The author suppose that the data are almost normally distributed (Figure 3.2). Conditioned on thr normality, the correlation coefficients are calculated. The result is that

could be suppose the absence of correlation (Table 3.2).

Chapter 4. The results of this chapter are published in two papers. One in a conference proceedings, the other in a journal. The bank deposits are analyzed by machine learning method and univariate ARIMA model. The author applies the Arcing method here at first. Three models are analyzed. An algorithm with machine learning on the data is applied. Then, the distribution of the transformed data are close to the normal. Arima is applied for modeling the residuums. The resulting model is called Arcing-ARIMA. The second model is applied to the original data. The third model is the Random Forests to the original data. The models could be applied to the short-term prediction.

In the **Conclusion** a short review of the results in the thesis is given. The scientific results and their applications are well explained in detail.

The Summary is written on 32 pages and the results obtained in the thesis are given. I think the results of the thesis mentioned of the author are true. The scientific contributions are well systematized.

Publications. The thesis is written on the basis of four published papers. Two of the papers are in proceedings of conferences. One is in journal with IF 1.2 (Q3), and one in Sciences of Europe. ISSN 3162-2364. The results of the thesis are reported during five conferences.

In the paper **P1** a new approach to modeling the financial time series is developed. The ARIMA model with four lagged variables and a trend as predictors is used. The authors mentioned that the use of lagged variables as predictors is a limitation.

P2 is on the results of forecasting the EUR/USD exchange rate. The results are given in the thesis.

P3 is on the time series of deposits in USDs. The models given here improve and upgrate the results obtained in the paper P1.

The paper **P4** is published in the journal Science of Europe, Phisics and Mathematics. The results are given in Chapter 3.

Remarks. It seems that [45] and [116] of the References are not cited in the thesis. I haven't any special remarks. My advice to the author is to continue the scientific work. This direction is very useful.

Conclusion. My opinion for the thesis is positive. The thesis represents a great deal of work. The results are well presented and their interpretation

and application are at a high scientific level. I didn't mention a plagiarism. I think, in such detailed analysis of real data is impossible to have a plagiarism. In my opinion, the thesis by Ivaylo Boyokliev fulfils the conditions for gaining the PhD degree in Mathematical modeling and application of mathematics. Therefor, I strongly recommend the thesis of receiving the Degree of PhD.

Sofia, March 2024

Leda Minkova