REVIEW

for the acquisition of **the ONS "Doctor"** in the field of higher education: 3. Social, economic and legal sciences, professional field: 3.8. Economics, doctoral program: "Finance, monetary circulation, credit and insurance" (Finance).

Reviewer: Prof. DS. Bojidar Violinov Bojinov, Department of Finance and Credit, D.A. Tsenov Academy of Economics, Svishtov , professor in scientific specialty 05.02.05 "Finance, Money Circulation, Credit and Insurance"

Author of the dissertation: doctoral student Antonio Valentinov Dichev (D010221294), full-time student in the doctoral program "Finance, Monetary Circulation, Credit and Insurance" (Finance) at the Department of Finance and Credit at the "D. A. Tsenov" University of Applied Sciences - Svishtov.

Topic of the dissertation: " Financial Risk Assessment Using Machine Learning"

On the basis of Art. 71 and 73 of **the Regulations for the Development of the Academic Staff at the SA "D.A. Tsenov"** and Order No. 1370/December 22, 2025 of the Rector of the SA "D. A. Tsenov" - Svishtov, I have been appointed as a reviewer in the procedure for the defense of a dissertation on the topic **"Assessment of Financial Risk through Machine Learning"** with author **Antonio Valentinov Dichev** , applying for the acquisition of the educational and scientific degree "Doctor" in the field of higher education: 3. Social , economic and legal sciences, professional field: 3.8 "Economics ", doctoral program: "Finance, Money Circulation, Credit and Insurance " (Finance).

This review has been prepared in accordance with the requirements of **the Act on the Development of Academic Staff in the Republic of Bulgaria,** the related **Regulations for the Implementation of the Act on the Development of Academic Staff** in the Republic of Bulgaria and **the Regulations for the Development of Academic Staff at the DA Tsenov University** .

The normative requirements for the dissertation work for acquiring the educational and scientific degree of "doctor" are available in Art. 27 of the Regulations for the Implementation of the Law on the Development of the Academic Staff in the Republic of Bulgaria and Art. 68 of the Regulations for the Development of the Academic Staff at the "D.A. Tsenov" Academic University, according to which:

(1) The dissertation must contain scientific or applied scientific results that represent an original contribution to science. The dissertation must demonstrate that the candidate possesses in-depth theoretical knowledge in the relevant specialty and the ability to conduct independent scientific research.

(2) The dissertation must be presented in a form and volume that meets the specific requirements of the primary unit. The dissertation must contain: title page; table of contents; introduction; presentation; conclusion - a summary of the results obtained with a declaration of originality; bibliography.

Art. 72, item 4 of the Regulations for the Development of the Academic Staff at the "D.A. Tsenov" University also implies the requirement to meet the minimum national requirements for acquiring the **educational and scientific degree "doctor"**

The starting point for the review is:
1. Dissertation " Financial Risk Assessment Using Machine Learning " in a volume of 197 pages. I accept the total volume as sufficient to clarify the author's thesis.

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2. A list of the candidate's publications on the topic, including the following publications:

1. Dichev , A., Zarkova , S., & Angelov , P. (2025). **Machine Learning as a Tool for Assessment and Management of Fraud Risk in Banking Transactions**, Journal of Risk and Financial Management, 18(3), p. 130. https://doi.org/10.3390/jrfm18030130
2. Dichev, A. (2023). **Discriminatory ability in assessing the probability of insolvency using some machine learning algorithms** , National Economic Archive, ISSN: 2367-9301, issue 4, pp. 17-30. https://doi.org/10.58861/tae.ea-nsa.2023.4.02.en
3. Dichev, A. (2023). **Machine learning in VaR as an assessment of market risk - advantages and disadvantages** . Annual Almanac "Scientific Research of Doctoral Students", ISSN: 1313-6542, issue XVI (https://www2.uni-svishtov.bg/almanahnid/title.asp?title=3048)
4. Dichev, A. (2025). **Ethics in the Age of Artificial Intelligence: "AI Laundering" (AIW)** . Proceedings of the Scientific Conference "Knowledge, Science, Innovations, Technologies" 2025, ISSN: 2815-3480, pp. 446-456

3. A list of contributions including 4 defined contributions, namely:

First. A systematic analysis of the concept of financial risk assessment using machine learning tools has been carried out. As a result, the key categories related to financial risk have been identified, their place in building financial sustainability models, and it is revealed that machine learning is a key catalyst for innovation in the study of economic and financial processes.

Second, empirical analysis reveals that in most cases, machine learning-based risk assessment models perform significantly better than those based on traditional methods. This, in turn, justifies the expectations placed on machine learning tools.

Third. The application, resource constraints, and situations in which machine learning financial risk assessment models are not sufficiently effective are outlined, including against the background of classical models, which emphasizes the need for their very precise contextual selection and application.

Fourth. Through a broad-spectrum empirical analysis, key challenges and limitations in the practical implementation of financial risk management models based on machine learning have been identified, formulating the conclusion that this toolkit is not a temporary technological phenomenon, but a natural and practically new evolutionary stage in the development of quantitative methods in finance.

4. Abstract in volume 31 pages.

5. A report on the fulfillment of the minimum national requirements and publications for the dissertation , with 4 publications listed, allowing for the acquisition of 40 points according to the national requirements.

6. List of the doctoral student's participation in scientific forums , with indicated participation in 2 scientific forums, namely:

1. Participation in the Doctoral Scientific Session 2023, held on December 1, 2023 at the Academy of Economics "Dimitar A. Tsenov" - Svishtov. As a result of the participation, an article was published : Dichev, A. (2023). Machine learning in VaR as an assessment of market risk - advantages and disadvantages. Annual Almanac "Scientific Research of Doctoral Students", ISSN: 1313-6542, issue XVI, Academic Publishing House "Tsenov", (https://www2.uni-svishtov.bg/almanahnid/title.asp?title=3048)

2. Participation with a report in the scientific conference "Knowledge, Science, Innovations, Technologies" 2025. As a result of the participation, a report was published: Dichev, A. (2025). Ethics in the era of artificial intelligence: "AI laundering" (AIW). Reports from the scientific conference "Knowledge, Science, Innovations, Technologies" 2025, ISSN: 2815-3480, pp. 446-456

The doctoral student has submitted the materials that are formally required for candidacy for the educational and scientific degree of "doctor".

In fulfillment of **my duties as a reviewer,** I present the following findings and conclusions:

I. General presentation of the dissertation work

Dissertation work " **Financial Risk Assessment Using Machine Learning** " in **a volume of 197 pages** . I accept the total volume as sufficient to clarify the **author's** thesis. The title fully corresponds to the content of the study.

The subject of the dissertation is formulated as " **the specific algorithms, tools and methods of machine learning that can be used for quantitative modeling and building effective tools for assessing the main types of financial risk - credit, market and operational. The analysis is focused on the possibilities and limitations of these methods within integrated risk management systems in the financial sector. "**

120 literary sources were used , of which 102 are in English and 18 in Bulgarian. The sources used are thematically related to the topic being developed and duly used in the dissertation work and, in my opinion, have been used correctly.

Structurally, the dissertation is structured neatly and logically – three chapters, an introduction and conclusion, and additional appendices. In my opinion, the structure of the dissertation, the balance between the parts, and most of all their content, present the doctoral student as an extremely conscientious researcher .

The first chapter is entitled **"THEORETICAL BASIS AND CONCEPTS OF FINANCIAL RISK AND MACHINE LEARNING"** and it provides a critical review of the essence, theoretical aspects and types of risk. The business model and business relationships within the scope of financial risk management (business risk), strategic decisions as a manifestation and significance for financial risk, and ESG factors as a form of financial risk are examined. The presentation provides a systematic and analysis of the concepts of machine learning in financial risk assessment, and of the leading research related to ML in financial risk assessment. Special attention is also paid to the regulatory framework in the European Union in the field of machine learning and artificial intelligence, with a focus on machine learning in the European Banking Authority (EBA) and as a technique for intra-bank modeling and determining capital requirements.

Chapter Two "METHODOLOGICAL ASPECTS OF FINANCIAL RISK ASSESSMENT THROUGH CLASSIC TOOLS AND MACHINE LEARNING" focuses on the possibilities for assessing credit, market and operational risk using traditional algorithms and methods and the related classification problems. Special attention is paid to the possibilities for risk assessment using machine learning methods, with an emphasis on the possibilities for analyzing sentiment and tone in text (Sentiment analysis), as well as on the applicable quantitative methods for model evaluation and validation (assessment of the discriminant ability (Somers'D / AUC), conservatism of the estimates (Binomial test), mean square error (Root Mean Square Error , RMSE), coefficient of determination (R2), SHAP (SHapley Additive exPlanations) and other metrics for evaluating a classification algorithm (confusion matrix).

The third chapter "PRACTICAL ASPECTS IN QUANTITATIVE ASSESSMENT OF FINANCIAL RISK. COMPARATIVE ANALYSIS OF THE REPRESENTATION

BETWEEN CLASSIC AND MACHINE LEARNING METHODS" focuses on the phenomenon of "AI washing" (AIW), the possibilities for modeling the probability of default (Probability of default , PD) in credit risk management, as well as for modeling value-at-risk (VaR). The author examines the possibilities of building a model for identifying fraud in card transactions, as a tool for managing operational risk, as well as the applicable ESG risks by modeling an ESG rating for companies in the S&P 500 stock index.

I accept the structure (and its corresponding research logic) as fully applicable to the researched issues, and the presented assessments and conclusions - accurate and correctly (personally) formulated.

II. Assessment of the form and content of the dissertation

The topic of the research is dissertable , relevant and significant from a theoretical and practical point of view. The title of the dissertation - " **Financial Risk Assessment through Machine Learning** " fully corresponds to the content. The author provides convincing evidence of the relevance of the topic on pp. 5-7, which allows me to confirm that the topic is original and relevant .

Object of research of the dissertation work is the financial risk. The subject of research is focused on the specific algorithms, tools and methods of machine learning that can be used for quantitative modeling and building effective tools for assessing the main types of financial risk – credit, market and operational. The analysis is focused on the possibilities and limitations of these methods within integrated risk management systems in the financial sector. *The object and subject are formulated correctly on p. 8.*

The main research thesis is, that "the application of machine learning methods can significantly improve financial risk assessment by more easily detecting otherwise hidden dependencies and interactions through automated processing of large volumes of data, including the ability to quickly adapt to dynamically changing conditions." (p. 8).

The goal of the dissertation is: revealing the potential added value of the application of machine learning as a tool for assessing individual types of financial risk. The approach to selecting algorithms and methods is based on a comparison between two families of algorithms – the so-called traditionally established (classical) methods for assessing financial risk and algorithms based on machine learning. The corresponding main research tasks are also correctly outlined (pp. 9-10). **I find** the goal and main tasks to be **correctly formulated** and provide sufficient opportunities for conclusions and recommendations.

The main research approach used in conducting the dissertation research is *the systematic approach,* which is combined with other research methods and scientific tools such as: statistical research, synthesis, induction, deduction, literature review, retrospective data analysis, graphical modeling, questionnaire survey. In order to highlight the path of development in quantitative methods related to financial risk assessment, a historical tracing and generalization was made, a systematization of the main theoretical and empirical research in the field of machine learning was also carried out, and through theoretical analysis and review of data from studies and publicly available sources, a selection of the most promising methods was made to be tested in the study. In relation to the data samples used, methods of the so-called. feature engineering , WoE transformation, Information value , grouping, etc. The quantitative aspect of the comparative analysis for the algorithms was performed by evaluating the discriminatory ability (Somers'D / AUC), conservatism of the estimates (Binomial test), precision (Precision), sensitivity (Sensitivity), specificity (Specificity), False Positive Rate (FPR), F1-score, root mean square error (RMSE), coefficient of determination (R2), SHAP analysis (SHapley Additive exPlanations) and others. Risk modeling was performed using various representatives of standard methods (logistic regression, GARCH) and machine learning (Gradient Boosting , XGBoost , Random Forest , FINBERT and others).

The limiting frameworks are described correctly (pp. 11-13).), including: all types of risk that have not been quantitatively assessed in this dissertation, indicators and aspects of credit, market and operational risk whose study would in practice make the study with an unclear horizon and limit the possibility of finalizing the study, a number of algorithms and methods that are recognized in society as impressive and promising, but due to practical considerations have not been considered.

The sources of the analyzed data are publicly available data, as well as analyses and research by leading economists in the field of this specific issue.

My general opinion about the dissertation work is that the author has clearly and precisely defined his views and ideas and within the framework of the dissertation has managed to argue and defend his views. A distinction is made between the achievements of scientific thought to date and the author's contribution to the researched issues.

The presented dissertation is 197 pages long, structured in three interconnected and building upon each other chapters. I believe that the volume of the research is sufficient for the doctoral student to develop and defend his/her view on the researched issues.

In support of the presentation in the dissertation, 43 tables, 34 figures and 26 equations have been created, which have a sufficiently high degree of informativeness and are directly related to the thesis and views of the doctoral student.

The dissertation is written in understandable language with correct use of specialized scientific terminology on the issue. There are no significant deviations from the theses in the presentation, repetitions of views and passages, as well as the presence of logical contradictions and proportionality of the parts. The calculations in the dissertation are based on established mathematical and statistical approaches and models, which are correctly and appropriately applied to the analyzed data.

The dissertation was checked using the "Antiplagiat" type system, according to which it is characterized by a similarity index within the levels permissible for scientific research, which is an independent confirmation that the author has strictly adhered to the rules of scientific ethics when creating scientific research , and has correctly cited the literary sources used.

Research and achievements have become available to the interested audience through 3 specialized publications on the topic - 4 articles. The publications reflect important aspects of the dissertation and do not overlap with each other, i.e. we do not have the publication of the same material under different names in different journals.

Regarding scientific and applied scientific contributions - there are some in the dissertation and, in my opinion, they are the author's personal work.

With regard to the fulfillment of the minimum national criteria for acquiring the educational and scientific degree "Doctor", a list of publications is attached to the dissertation, which shows that the minimum national requirements in this area are met.

Regarding the volume and content of the abstract, I believe that it is of sufficient volume and correctly, completely and accurately reflects in a summary the content and achievements of the author's dissertation research.

III. Scientific and scientific-applied contributions of the dissertation work.

Submitted for review is a completed scientific work on the topic " **Financial Risk Assessment Using Machine Learning** ". Within the framework of the research conducted, the author reaches a conclusion and upgrades, separated within 4 contributions, indicated in the attached abstract.

Among the author's achievements we can highlight:
- A systematic analysis of the concept of financial risk assessment using machine learning tools, based on which key categories related to financial risk and their place in building financial sustainability models have been identified.

- Empirical analysis has shown that risk assessment models based on machine learning predominantly perform significantly better than those based on traditional methods.
- The application possibilities, resource constraints, and situations in which machine learning financial risk assessment models are not sufficiently effective are clearly defined, including against the background of classical models, which emphasizes the need for their very precise contextual selection and application.
- Based on a broad-spectrum empirical analysis, key challenges and limitations in the practical implementation of machine learning-based financial risk management models have been identified.

Personally, I do not know whether the ideas and results proposed by the author have found resonance and recognition in the specialized scientific literature.

IV. Critical notes, questions and recommendations on the dissertation.

In science, there is never a study that we can say is completely finished and has no potential for future development and improvement. The same applies to the current dissertation.

I have the following additional questions for the doctoral student related to the topic of the research he conducted:

1. To what extent are causality and data drift problems in machine learning? If so, what approaches could be used to address them?
2. Expertise in areas such as machine learning and artificial intelligence is proving to be key and in short supply, according to your work and the regulatory challenges outlined. Do you believe that this expertise should be built internally in the respective organization implementing these tools or should it rather be outsourced? Can you highlight the benefits and drawbacks of both approaches?

V. Summary conclusion and opinion.

__My general opinion is:__ the author has developed a dissertation that has a clearly formulated problem, goal and tasks, implying scientific research; the dissertation is proof that **Antonio Valentinov Dichev** knows the scientific literature and scientific achievements in this scientific field , has identified significant problems, has systematized the researched issues, has correctly interpreted the results of the scientific research, has formed them and presented them in an understandable and logical way. The dissertation work contains scientific or scientifically applied results that represent an original contribution to science and shows that the candidate has in-depth theoretical knowledge in the relevant specialty and abilities for independent scientific research.

This is a reason to give my support through a positive assessment **of the dissertation work of Antonio Dichev , and** to recommend to the members of the scientific jury **in** the procedure **for the public defense of a dissertation work on the topic " Assessment of financial risk through machine learning ",** to award doctoral student **Antonio Valentinov Dichev** the educational and scientific degree "doctor" in the professional field 3.8. Economics, in the scientific specialty 05.02.05. "Finance, money circulation, credit and insurance" (Finance).

Date: 14/01/2026   Reviewer: ....

Svishtov

(Prof. DS. Bojidar Bojinov)