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Dr hab. Tomasz Bernat prof. US
Uniwersytet Szczeciński
Instytut Ekonomii i Finansów
Katedra Ekonomii

Review of the doctoral dissertation by Raphael Korbinian Reinwald

On a Comparative Analysis of Industrial Credit Portfolio Risk Models Versus a New Support Vector Machine - Based Approach

Supervisor: **Prof dr hab. Michał Suchanek**

Scientific Value of the Dissertation

Originality of the research

Artificial intelligence algorithms used in various areas of human life have an increasingly significant impact on the well-being of mankind. This applies to both the support of human decisions and their complete replacement by "computers". Broadly speaking, there are two opposing views regarding AI applications: fear of its application and full support. Based on statements by Elon Musk, Steve Wozniak, Bill Gates, Bill Joy, and Stephen Hawking and signed by them the open letter in 2015, it is clear that what everyone is afraid of is 'unfriendly AI' and what everyone wants is 'friendly AI'. The terms "friendly" and "unfriendly" do not refer to any particular "personal" feature of an AI system. These terms refer to whether artificial intelligence activities will have a positive or negative effect on humanity. Our fear creates regulatory actions that can hinder the development of artificial intelligence. However, the suppression of such innovative activities is a denial of Schumpeter's creative destruction and rapid growth. Humanity therefore faces a serious dilemma regarding the development of these technologies.

The work of Mr. Raphael Korbinian Reinwald is embedded in the aforementioned realities regarding the use of artificial intelligence algorithms "New Support Vector Machine" to assess one of the departments of human business activity, which is the assessment of credit risk.

The main objective of the research is to compare various models of the credit portfolio and to demonstrate that the application of the support vector machine (SVM) approach is adequate for the measurement of the risk of the credit portfolio. Moreover, confirmation that for some of the portfolio models indicated by SVM performs better than the commonly used industrial models. The implementation of such a formulated goal required the adoption of a broad definition of many concepts related to finance, investment assets, debt instruments, risk, risk management or building a credit portfolio, as well as concepts related to artificial

intelligence algorithms. Apart from their presentation, the author presented his own calculations using two models - the classic one used by the banking sector and the model using artificial intelligence. In his work, he put forward 3 research hypotheses.

The implementation of the goal set and the verification of the hypotheses required the adoption of specific research methods, which were divided into two stages. First, the Ph.D. student conducted a very detailed literature review corresponding to the need to explain often complex concepts and definitions. Then, on the basis of selected debt instruments issued by large enterprises in Europe and the USA, divided into 2 groups: low and high volatility, he compared the portfolios based on previously created criteria. It finally allowed us to draw correct conclusions from the research carried out in the dissertation.

The thesis has a few minor shortcomings, for example, it is not fully known, at least from the introduction, whether the PhD student takes into account the banking sector, other institutions on the financial market or the entire financial market - it has not been clearly and unambiguously defined.

It is worth mentioning, however, that despite a very large theoretical load, the work may have an application character because the presented research can also be interpreted in this way.

The Scientific Value of Chapters

The dissertation consists of five chapters divided into theoretical parts, where various concepts and definitions, models, ratings, and determinants are analyzed (which takes up most of the doctoral dissertation) and the empirical part is definitely smaller. In addition to the above-mentioned parts, the work includes an introduction, final conclusions, a bibliography, various lists, and 3 annexes. The Appendices present the codings necessary for the computational process and the stochastic assumptions of the research.

The work is structured in a logical way. First, theoretical aspects are discussed; the first four chapters are devoted to this. In Chapter 5, apart from issues related to the functioning and models of artificial intelligence, research assumptions, research models, and the final results are presented.

The **first chapter** introduces concepts related to asset classes and types of investment portfolios. The terms that are defined and widely discussed here include, among others, equity capital, the bank's own funds, debt instruments, and alternative asset classes. The characteristics of these asset classes are described, and the first (credit) risks arising from them are listed. In addition, the collections of these assets that constitute a portfolio or a specific type of fund are described, as well as their respective investment styles and strategies. It also introduces risk and return measures and indicators to measure the effectiveness of the strategy.

The **second chapter** describes in detail the risk and its various types that occur in banking, mainly including credit risk. The principles of risk management and formalized risk measures will also be presented. The principles and theory of creating optimal portfolios in

terms of risk / return characteristics are also shown here. One of the elements of this chapter are also innovative ideas related to the incorporation of behavioral components and machine learning techniques into portfolio management. However, it is a pity that when describing risk and the concepts related to it, the Ph.D. student did not mention one of the fundamental scientific works in this area, namely the work of F. Knight "Risk, Uncertainty and Profit" from 1921. It is a classic work, but its influence on contemporary knowledge appears to be important.

The **third chapter** presents ways to build ratings and risk models. Among other things, credit risk management models, internal and external rating processes, systems, and techniques for validating these systems (models) are presented. An important element of the chapter is quantitative models for various types of banking risk, commonly used in academic research and in practice in the financial industry.

The **fourth part** of the work is an analysis of methods and a detailed comparison of industrial models in relation to a selected class of debtors. The transformations between the two main types of models are also shown here, as well as the equivalences within the unified framework. An extensive review of the literature was used to provide an overview of the current state of research in this field.

In the **final chapter 5**, a novel approach to credit risk measurement using carrier vector regression is presented. The supported vector machines adopted are a machine learning classifier (SVM) or a regressor (SVR) technique. Their goal was to categorize data into two or more iterative classes or to approximate a given function using a multidimensional (backward) transformation and the so-called "Kernel functions". This chapter also presents the methodological foundations and calculations within the framework of the assumed comparisons between the adopted models.

The fifth chapter logically closes the whole work by combining elements of theories described in the previous parts, as well as the research and comparison of models.

The dissertation is finished with the **concluding part** in which the most important results are discussed: verification of research hypotheses, a discussion on possible interpretations of the results achieved. The conclusion also indicates the positive and negative sides of the use of artificial intelligence algorithms to assess the risk of credit portfolios. It also indicated the possibility of conducting further scientific research on the discussed topic, including machine learning.

The analysis of individual chapters of the dissertation presented above is a well-structured and logical approach to research in this area. To a large extent, it presents the theoretical basis necessary to conduct the designed research and, on the other hand, it bases the research on an adapted research methodology. This is the correct form of presenting a scientific achievement. It is also worth pointing out that with such a large volume of work and a large amount of theoretical material presented, the PhD student presents it in a detailed and at the same time transparent manner. The graphs, very well woven into individual parts, are a great help in completing the next dissertation cards.

The high rating of this work is also justified by the number of scientific papers used by the PhD student. It is a total of 1202 works. Such a large number of papers cited shows both the complexity of the topic and their very good use in the dissertation. This is undoubtedly an advantage of this job.

Substantive value of the dissertation

Quality in the dissertation can be assessed through several important components, including, among others, the ability to introduce the topic into the research, the clarity of the construction of research goals and hypotheses, the proper selection of research methods, the presentation, and interpretation of the results obtained against the background of previous research in a given topic. Referring to the presented doctoral dissertation of Mr. R Reinwald, I state that all the above-mentioned elements of the substantive evaluation receive my high positive assessment. Below, I present my comments on the construction of the part of the dissertation devoted to goals and hypotheses.

The Ph.D. student has presented the basic research goal, which is as follows: "*The main aim of the thesis is to introduce a credit portfolio model which is effective (compared to a linear model) and even a better predictor than current credit portfolio models for some common bond portfolios*". It is quite a complicated structure that could be successfully presented in the form of two separate goals, one related to the effectiveness of the credit portfolio and the other related to the comparison of their predictions. This goal is recorded in the introduction. Similar sounding, but different, is written in the abstract: *The aim of the thesis is to compare credit portfolio models and to show that a novel approach based on support vector regression is suitable to measure credit portfolio risks and is even of superior performance compared to current industrial models for certain portfolios*. The emphasis here is on comparing credit portfolio models and identifying a new research approach. Therefore, it is difficult to clearly conclude what this work is about; nevertheless, all the problems raised in both main objectives are discussed in detail in the dissertation. It is worth the PhD student to clearly present the purpose of the work.

Based on the above different objectives, the Ph.D. student proposed 3 researchers' hypotheses. They are as follows:

H1: The SVM regression (SVR) model is an effective model for credit portfolio risk (CPR) measurement of typical bond portfolios.

H2: SVR's “error” is smaller.

H3: The SVR method may outperform even the classical models for a majority of selected standard bond portfolios.

For each of the above-mentioned hypotheses, their operational versions necessary in the computational process were also presented.

For H1: H0: The predicted distributions of values from LM and SVR are equal (stemming from the same population). LM ~ Kruskal-Wallis SVR.

For H2: H0: RMSE (LM, real portfolio data) ≤ RMSE (SVR, real portfolio data)

For H3: H0: Min (CreditMetrics® VaR - real VaR; CreditRisk + ® VaR - real VaR) ≤ (SVR VaR - real VaR) - for the majority of the portfolios.

The construction of the main hypotheses raises some suggestions and questions. Hypothesis 1 is properly prepared. For Hypotheses 2, one should elaborate on its main idea: SVR's "error" is smaller, but in relation to what? To what extent - if so assumed? How should you understand the term error? Hypothesis 3 contains the word "even", which seems unnecessary, as it "blurs" this hypothesis. It would also be worth indicating what the concept of "outperform" is in relation to - the quality of calculations, error size, and risk level?

These aforementioned inaccuracies in the goals and hypotheses cause a misunderstanding of the actual intentions of the Ph.D. student. This is important because the work is largely a review of the literature, while the goals and hypotheses are directed to the empirical part. It would probably be worth considering here creating an additional goal, and perhaps a hypothesis, which would take into account the "Sisyphean" workload of the PhD student on the review of literature and research.

The adopted methodology of research - comparative analysis is appropriate. This is due to the subject of the research and the assumptions made. The subject of the research are credit portfolio models affected by a huge amount of data. The author solved the data problem using the recognized and accepted in practice ratings of well-known consulting companies. On this basis, he constructed and designed his own computational model using an artificial intelligence algorithm, which was compared with the existing classic models used in economic practice. This is the right way to do research. At this point, it is worth mentioning once again that the Ph.D. student had to spend a lot of work processing the collected literature material.

From a technical point of view, in the part dedicated to methodology (chapter 5), apart from the hypotheses and the research methods carried out, the main objective (s) of the research should be indicated again. It would also be useful to technically highlight those workplaces where goals and hypotheses are presented, for example, in bold writing. This would construct this part of the work more clearly and facilitate the analysis of this complex material.

Editorial correctness of the dissertation

The formal assessment of the editorial accuracy of the presented doctoral dissertation is very high. It consists of 373 typescript pages, including all lists and annexes. Therefore, it is a long work containing a lot of theoretical and practical knowledge processed. One can see that it is refined in terms of graphics, technical, and text. This makes it easier to read and understand the knowledge transferred. Charts and tables are placed in the right places with appropriate markings and descriptions pointing to their most important elements. The pages are numbered correctly. The numbering of tables and charts is correct. It should be noted that in the work the author created a large number of charts and tables, which result from the large amount of processed basic material; this is a strong element of this work, facilitating the

understanding of numerous areas of knowledge raised. The paper adopts the convention of indicating end references, which is the correct way to prepare the paper.

The only minor drawback of the presented doctoral dissertation is the lack of distinctions in the text of the most important information. This can be done very simply by bolding specific parts of the text (as mentioned for objectives and hypotheses). This would allow to concentrate on the essentials of your work.

The dissertation has a small number of typographical or grammatical errors, but the few exceptions do not change the overall very good assessment.

Substantive comments

Each scientific dissertation should be subject to evaluation, which includes a critical analysis of the presented research material. It is not different from the case of Raphael Reinwald's dissertation. In the following, I present some substantive comments on the research methodology.

The presented work is an interesting study on an issue very important from the point of view of every entity, in particular a financial institution, investing in the capital market. The main problem that has been presented in this paper is whether artificial intelligence algorithms - under the name "Support Vector Machine", are more efficient in assessing portfolio credit risk. Although the work concerns institutional investments, it is quite easy to imagine a similar application for individual investors. Accepting such a problem (and having goals and hypotheses based on it) causes several basic problems that the doctoral student had to face. They are as follows: a huge number of growing investment opportunities in the form of new instruments (e.g., cryptocurrencies), a multitude of increasingly complex ways of managing credit risk, complex methods of interpreting and calculating risk, and a variety of methods and principles of creating investment portfolios. Moreover, there are also artificial intelligence techniques, which are becoming more and more specialized and at the same time more complicated. The doctoral student coped with all this, constructing his dissertation based on a very detailed review of the professional literature, showing the current state of knowledge in the field of research. This is undoubtedly a huge advantage of this work, which is visible in its structure. In fact, the first 4 chapters are theoretical parts. In chapter five, however, two of the four subchapters are empirical. The enormity of the knowledge that was presented certainly allowed for a very precise and proper preparation and conduct of the study - in a sense an experiment comparing different methods of building and assessing a credit portfolio. I positively assess such a dissertation preparation.

Research Methodology

The research methodology for work is described mainly in chapter five, which also presents issues related to the technique of artificial intelligence. The aims of the study, although presented in a rather chaotic way, as well as 3 hypotheses, are discussed in the Introduction and in the empirical part. They are presented in the right places related to the dissertation being carried out, although, as I indicated above, they have several inaccuracies.

In the conclusions, the doctoral student indicated exactly how the hypotheses were verified, but it is not shown whether the goals set in the work were achieved, although this is the case.

For the purpose of conducting a comparison of credit risk assessment methods, the doctoral student used both the acquired and processed knowledge, statistical methods related to the construction of the credit portfolio for the classical and artificial intelligence-based approach. The use of these methods was possible thanks to data that came from important data sources such as Bloomberg.

The implementation of the selected research material in accordance with the proposed methods allowed the verification of the hypotheses. This allows the conclusion that the regression based on support vector machines is highly effective and may be a valuable tool in the assessment of credit risk. Thus, the adopted research methodology, including extensive preparation for them, should be considered appropriate and allow implementation of the assumptions made.

Questions for the doctoral student

1. The main idea of the thesis is that artificial intelligence methods give better results in risk prediction and portfolio building than currently used solutions. If and to what extent could it be admitted to the portfolio of instruments that are riskier than just bonds? Since artificial intelligence methods give better results, maybe the next step will be to expand the portfolio base?

2. Analyzing the theories presented in Chapter 2, we come across a general model of building an optimal, effective, portfolio (p. 108). Does the Ph.D. student think that such a concept is consistent with Pareto efficiency, which is also used to theoretically justify the effectiveness of economic decisions? How does this coincide? How, then, could one define what an optimal portfolio is in the Pareto efficiency sense?

3. Making decisions. Decisions are usually based on the analysis of available decision-making factors. In the case of people, regardless of the number of things that affect a person, all kinds of emotions, prejudices, experience, and intuition come to the fore. With regard to artificial intelligence models, this element is eliminated. The machine makes decisions with the help of certain criteria and an algorithm, without any emotions. However, it should be remembered that algorithm programming, and perhaps machine learning itself, has an emotional component. So, is it possible to eliminate human emotions and does it really allow for greater efficiency, improving the optimality of building a credit portfolio?

Final mark

The general assessment of the doctoral dissertation of Raphael Reinwald is positive and, as a scientific study, emphasizes the value of the scientific maturity of the doctoral student. He managed to achieve the set scientific goal, emphasizing his great knowledge of the problem at the same time. My assessment is also influenced by the analysis of the process of scientific cognition in accordance with the canons in terms of defining the research problem and correctly conducting argumentation, especially in its empirical layer. A comprehensive,

systematic, and insightful review of the literature has been conducted. This approach should be considered correct and methodically justified. The accuracy of the observations with respect to the problem under study also deserves praise. The comments noted in the dissertation and included in the review do not diminish its substantive value.

I conclude that the thesis of Raphael Reinwald entitled “On a Comparative Analysis of Industrial Credit Portfolio Risk Models Versus a New Support Vector Machine - Based Approach” meets the requirements of Art. 187 of the Law on Higher Education and Science of 20 July 2018. (Journal of Laws 2018, No. 65, item 1668). Based on what is stated above, I recommend that permission for a public defense of the dissertation can be granted.

Therefore, I am applying for admission of Raphael Korbinian Reinwald to the next stage of the proceedings: public defense. Considering the high cognitive value related to a very difficult issue and, at the same time, very modern related to our future, as well as for a very thorough analysis of the collected research material, I also request that the dissertation be distinguished with the appropriate award of the Rector of the University of Gdańsk.

October 21, 2022

Tomasz Bernat

date of the review signature of the reviewer