



Sofia University "St. Kliment Ohridski"

Faculty of Economics and Business Administration

REVIEW

By: Assoc. Prof. Kaloyan Ganev, Faculty of Economics and Business Administration, Sofia University "St. Kliment Ohridski"

Regarding: Dissertation for award of educational and scientific degree "Doctor" in scientific specialty 3.8. Economics

Reason for submitting the review: Order RD 38-454/19.07.2023 of the Rector of Sofia University "St. Kliment Ohridski"

Author of dissertation: Mihail Veselinov Yanchev

Topic of the dissertation: "Modeling Economic Uncertainty: Methods, Evaluation, and Applications of Probabilistic Forecasting"

1 Information on the dissertation author

Mikhail Yanchev holds a Bachelor's degree in Economics from Adelphi University and a Master's degree in the same field from Fordham University, the United States of America. Since July 2020, he has been a Ph.D. student at the Department of Economics and Management of Industries of the Faculty of Economics of Sofia University "St. Kliment Ohridski".

The thesis author's professional career began in 2012 when he started working as a macroeconomist at the Bulgarian National Bank, where he remained until 2015. From 2015 to 2018 he held the position of *credit risk modeling expert* at the commercial bank Eibank EAD. From 2018 to 2019, he held the position of *quality assurance engineer* at the private company CWT Consulting. From 2019 to 2020, he worked as a data science consultant at Grid Search, and from November 2021 onwards he has been a data science team lead at Prime Holding.

He has an excellent command of the English language and also uses German.

2 General assessment of the submitted dissertation

The submitted dissertation consists of a total of 157 pages (including the title page). Its structure includes an introduction, three chapters, conclusions, a list of references and four appendices. There are 18 tables and 33 figures. The number of references used is 337.

The chosen topic of the dissertation has an unambiguously clear relation to both fundamental and current issues of economic science and practice. The issues of uncertainty in the economic context, to which it is devoted, not only continue to occupy an important place in theoretical debates and new developments in economic science, but are also becoming increasingly important in practice. This importance is underlined daily by the development of applications of mathematics, statistics and information technology in the processing, modelling and forecasting of a wide range of economic and other related indicators. In this sense, there is no doubt that the thesis is extremely topical.

The structure of the dissertation as a whole is in line with the requirements and traditional practice of organizing such documents, both domestically and abroad, as far as the acquisition of the degree "Doctor of Economics" is concerned. The text is written in excellent English and it is substantive and informative. It demonstrates the high level of the author's training in economics and traditional economic modelling, as well as in areas of quantitative analysis that are developing rapidly in modern times (in particular machine learning techniques and their empirical implementation in a computing environment). It is evident that the substantial practical experience of Mr. Yanchev, accumulated over the years of his professional biography in various areas of applied work in the public and private sectors of the Bulgarian economy is also reflected in the text. The work is characterized by considerable depth and excellent knowledge of the literature. It demonstrates a broad scope extending even beyond the boundaries of pure economics. The author demonstrates a good command of the concepts and tools of the philosophy of science and the ability to use them to achieve the goals set.

The introduction of the dissertation provides a general characterization of the uncertainty concept, outlines the author's assessment of the relevance and significance of his work, defines its object and subject, as well as the main research goals and tasks. The research working hypotheses are described and the scope of the study is sketched. The gen-

eral characteristics of the methodology followed are stated, and the data sources and software applications used for the specification and empirical evaluation of the constructed models are briefly highlighted. In this section, the individual chapters of the thesis are also briefly summarized, with a little more detail given to the three case studies implemented within the third chapter.

The first chapter is devoted to the definition of the concept of uncertainty and to its classification by types for the purpose of economic forecasting. It traces its scientific treatment in historical perspective, starting with the work of the ancient Greek philosophers, going through the Middle Ages and reaching the present day. The focus on economic uncertainty is delineated, and the specifics of so-called Keynesian uncertainty, Knightian uncertainty, aleatory and epistemic uncertainty, and the interaction between the latter two are discussed in detail. The main approaches used in economic forecasting are discussed: structural and non-structural models, time series models, as well as several classes of models possessing advantages in forecasting using large information sets (MIDAS, dynamic factor models, etc.). Attention is also paid to combining (averaging) forecasts produced using multiple models. Details related to the generation of interval, quantile and density forecasts are also reviewed, and some key definitions and technical specifics (confidence and prediction intervals, quantile regression, etc.) are included in this context. Some principles related to the quality assessment of density forecasts are also outlined.

In the second chapter, the focus is on probabilistic forecasting using artificial neural networks. In particular, attention is paid to generating density forecasts with their help. A new method called *deep quantile probabilistic regression* is proposed. Part of the chapter is concerned with finding a quantitative expression of uncertainty of the epistemic type using artificial neural networks. Another part deals with the possibility of separating epistemic from aleatory uncertainty by applying the law of total variance. However, it is explicitly noted that separation is not always possible, in particular if such purely mechanical methods are applied. The third part of the chapter is devoted to metrics for assessing the accuracy of forecasts. Models are defined there to be used as reference points for comparison of the results obtained. Finally, the chapter addresses the important issue of the ability to explain the results obtained, an element of analysis that is often considered a weakness of neural network models. In this case, the author shows that such a possibility is available.

The third chapter of the dissertation contains the empirical applications carried out by the author. They are three in total, i.e. three case studies are considered: 1) ‘now-casting’ with respect to the 2020 coronavirus pandemic-induced recession in small open economies; 2) probabilistic forecasting of natural gas prices transported through the Balkan gas hub; 3) Measuring aleatory and epistemic uncertainty in forecasting consumer price inflation in Bulgaria. For each of these, there is a proper description of the case study, the data and results used, detailed graphical and descriptive statistical material, and subsequent discussion.

The conclusion includes a summary of what has been achieved in the dissertation,

including a statement of contributions, originality and significance of the research. At the same time, the author has outlined the limitations of the dissertation and indicated possible directions for future work on the topic.

The list of references is correctly formatted, following a unified format for the bibliographic units. The in-text citations are also correct.

Appendix A provides additional details related to the optimization of the loss function used in estimating the deep quantile probabilistic model. Appendix B contains a comparative analysis of the alternative use of the sinh-arcsinh family of probability distributions and the skewed t -distribution. Appendix C includes a list of indicators used in the exploratory analysis, and Appendix D shows the results of applying bootstrap sampling to assess the statistical significance of the estimated three types of model metrics applied to the Balkan Gas Hub case study.

3 Evaluation of the scientific and applied scientific results obtained

The results obtained in this thesis can be evaluated in several directions. First, they are the result of a correct and competent application of the methodological frameworks used. There is no doubt that the author understands both the substance and specifics of the theory, as well as the important details related to the proper selection and adequate use of the relevant models and techniques. Second, the results are wide-ranging (as a consequence of the heterogeneity of the case studies and the range of indicators studied in each of them) and allow for a sufficiently well-founded judgement of their universality. Third, they are interesting insofar as they have direct practical relevance, but also because of the new methodological knowledge on which they are based.

4 Evaluation of scientific and applied scientific contributions

Both purely scientific and applied-science contributions have been achieved in this dissertation. One of the purely scientific contributions consists in the formulation and proposal of a new method called *deep quantile probability regression*. Two others are methodological in nature. One consists in the development and application to data for Bulgaria of a Bayesian variant of deep quantile probability regression, and the other – in the application of the LIME¹ algorithm to the same model. The scientific-applied contributions, according to the author, consist in the demonstration of the superiority of the proposed model over the selected benchmark models. Here, I would add that the results of the

¹Local Interpretable Model-agnostic Explanations.

benchmark models can also be attributed to these contributions, insofar as so far in the Bulgarian literature their application to this type of data is rather extremely rare. In general, I believe that the contributions are original and constitute an indisputable basis for awarding a PhD degree.

5 Evaluation of the dissertation-related publications

In connection with the defence of the dissertation Mr. Yanchev has submitted two publications. One of them is in the Economic Studies journal. The other one is in the Bulgarian Economic Papers series of the Faculty of Economics of Sofia University “St. Kliment Ohridski”, for which a standard reference note has been completed by the author. However, I believe that there is some inaccuracy in the reference note: the publication in the Economic Studies journal is 22 pages long and should therefore be classified as the type listed in Group D.8 of the Regulations for the Implementation of the Academic Staff Development Act. The latter means that the publication carries not 30 (as stated in the reference) but 45 points. This brings the number of publication points to 55, which exceeds the required minimum (the minimum is exceeded even without this clarification). Qualitatively, both publications confirm the excellent impression left by the dissertation itself.

6 Evaluation of the dissertation summary

The dissertation summary is presented in both Bulgarian (67 pages) and English (57 pages). In general, it is correctly formatted, following the established standard. Its structure and content objectively reflect the content of the dissertation, the main results achieved and the conclusions drawn. Contribution statements have been repeated.

My overall assessment is that the dissertation summary meets the requirements, but once again I believe that its submission is a requirement that has long been out of step with the times, represents an unnecessary burden on both PhD students and reviewers, and should be considered for removal from the regulations.

7 Critical comments, recommendations and questions

Despite my overall positive impression of the thesis, I take the liberty to make some critical remarks and recommendations. The first of these are of a more general and principled nature, while the second are more technical and editorial.

The general remarks and recommendations are as follows:

1. It seems to me that the first part of the introduction is written a bit carelessly. Moreover, in my opinion, there is a certain vagueness in this place as regards the content and meaning of the terms ‘risk’ and ‘uncertainty’. Certainly, in the main text of the thesis this flaw is absent, but it should nevertheless be borne in mind in future work, as it may leave initial negative impressions on readers.
2. The first two chapters contain mainly a literature review and some theoretical generalizations. These take up a rather large proportion of the dissertation and thus create a certain structural imbalance (in particular making the empirical third chapter seem somewhat detached and lagging in the text). I admit that I personally found their contents very interesting to read, but I think this approach is more appropriate for a book than a dissertation. In this sense, while it reveals the author’s high level of erudition, it would have been appropriate to replace it with an overview that is more synthesized and more focused on the narrow area of study.
3. In confirmation of the preceding remark, for example, attention is drawn at a certain point in the thesis (p. 16, last paragraph) to F. Knight’s opposition against Keynes’s liquidity preference theory. On the basis of this correct observation, however, it is concluded that Knight is an opponent of Keynes in principle. Although the historical facts generally support such a conclusion, the above observation *per se* is not sufficient to reach it. In this sense, the paragraph (as well as some others) can be considered more of a curious quibble than something necessarily to be noted in one’s dissertation (as the PhD student has claimed).
4. The term “unexpected shock” is used several times on p. 5 and onwards. Viewed in principle, this concept is on the one hand a pure tautology, since a shock itself is something unexpected.² On the other hand, assuming there are other shocks, they must be expected ones, which creates an oxymoron. A search of the World Wide Web shows that this phrase, while quite rare, has managed to find its way into even some of the most reputable journals.³ Of course, this does not constitute a reason to extend such a practice. I could not identify a clear definition in the dissertation of this concept. I can only assume that it refers to so-called black swans or, in other words, to events found far in the tails of probability distributions (tail events, or tail shocks), etc., that have a disproportionately large impact on important (economic) indicators. I hope this will still be clarified during the defence.
5. The review of the development of economic forecasting could be complemented (around page 30) with the development of the cointegrated VAR model (VECM), starting with the error correction model developed by D. Sargan and especially by D. Hendry and reaching to the key contribution of S. Johansen and others.
6. On page 22, the definitions “accurate and unbiased” are used in relation to the estimates. While unbiasedness is generally an unambiguous concept, precision requires

²At least as far as the economic context is concerned. See for example [https://en.wikipedia.org/wiki/Shock_\(economics\)](https://en.wikipedia.org/wiki/Shock_(economics)).

³For example, Baker, S., McElroy, T., and Sheng, X. (2020): “Expectation Formation Following Large, Unexpected Shocks,” *Review of Economics and Statistics*, 102 (2), pp. 287-303.

an appropriate definition since (especially for continuous variables) any forecast is practically inaccurate.

7. Page 26: I note here that the foundations of the input-output analysis of Leontief should be sought as early as 1925.⁴ There are a number of other publications by the same author published before the work on American economics cited by the PhD student.
8. I recommend that the author devote more space in future publications to a more extended theoretical description and investigation of the properties of his proposed deep quantile probabilistic model.

The list of technical notes and recommendations includes the following:

1. Page 22: there is a typographical error. X_{T-h} and Y_{T-h} should actually be X_{T+h} and \hat{Y}_{T+h} . The hat on Y is necessary to make it clear that we are talking about an estimate, not an actual value (as correctly denoted later in the dissertation). Accordingly, the forecast distribution should be denoted by $f(\hat{Y}_{T+h}|\mathcal{D}^T)$. In this case, it is not necessary to use an asterisk in denoting the distribution of future actual realizations of the variable, i.e., it is sufficient to write $f(Y_{T+h}|\mathcal{D}^T)$. It is perhaps worth noting here that if the information set has no relation to the realizations, then the distribution becomes an unconditional one. The information set itself should also be written as $\mathcal{D}^T = (Y, X, X_{T+h})$, or better yet as $\mathcal{D}^T = (Y_T, X_T, X_{T+h})$ to explicitly indicate that Y_T and X_T contain the entire history up to and including time T .
2. Page 22: assuming that the two vectors X and Y are each characterized by N observations and each pair of elements $(x_i, y_i), i = 1, 2, \dots, N$ is considered as one element of the information set, then its size would indeed be N . However, adding X_{T+h} results in a size of \mathcal{D}^T that is equal to $N + h$. This does not change the reasoning and conclusions from here on (in particular when going to the asymptotic case), but it is still good to have precision.
3. Page 23: “predictive distribution” in this context seems to me to be a rather inadequate term as it has a more specific meaning used predominantly in Bayesian statistics, and this does not seem to be the case. Rather, I believe that “forecast distribution” should be used.
4. Page 27 and thereafter: “structural forecasting” and “non-structural forecasting” are also defined as “macroeconomic”. This is somewhat limiting insofar as the same or very similar approaches have been applied in microeconomic modelling. It is more appropriate to use simply “economic” instead of “macroeconomic”.
5. Page 74: to the metrics described, a “mean absolute percentage error” (MAPE) could be added, since in the case of mean absolute error (MAE), for example, the result is

⁴Леонтиев, В. (1925): „Баланс народного хозяйства СССР. Методологический разбор работы ЦСУ”. *Плановое хозяйство*, No. 12, изд. Госплана СССР.

dependent on the scale of the data itself and this can make interpretation difficult. MAPE is scale-free, which is a significant advantage.

6. Page 10 of the thesis summary: it is not appropriate to copy the content of the thesis a second time in the text.

I have no further questions for the thesis author.

8 Conclusion

In spite of the remarks and recommendations made, I believe that the presented dissertation is a study of high quality, significantly above the average level of dissertations defended in our country in the field of economics and management. I hope that the author will perceive the criticism only as constructive and that this will help him to continue to develop in the field of this type of knowledge and its applications.

Mr. Yanchev has also fulfilled all the legal requirements for obtaining the degree of "Doctor", stipulated by the Law for the Development of Academic Staff in the Republic of Bulgaria, the Regulations for its implementation and the Regulations for the conditions and procedure for the acquisition of scientific degrees and the holding of academic positions at the Sofia University "St. Kliment Ohridski".

On the basis of the above, I consider that the overall performance of the candidate should be awarded an excellent mark. I therefore take the liberty of recommending the distinguished scientific jury to vote in favour of the award of the degree of PhD in the professional field 3.8 Economics to Mihail Veselinov Yanchev.

Sofia,
September 28, 2023

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/Assoc. Prof. Kaloyan Ganev/