A REVIEW

of the dissertation for the award of the academic degree "Doctor" on the topic:
APPLICATIONS OF DATA ANALYSIS ALGORITHMS

Doctoral candidate: Boyko Amarov
Supervisor: Prof. D.Sc. Ivan Ivanov
Reviewer: Prof. (Assoc.) Victor Ivanov Yotzov, PhD, Department of Finance, UNWE

1 CANDIDATE INFORMATION

Distance-learning doctoral candidate Boyko Amarov obtained a bachelor's degree in statistics from Freie Universitat in Berlin in 2007 and a master's degree in business administration from the same university in 2008. He has held a position as a research associate at Freie Universitat Berlin, as well as various consulting positions in Germany and Bulgaria. Since 2017, he has been an assistant at the Department of Statistics and Econometrics at the Faculty of Economics and Business Administration (FEBA), Sofia University "St. Kliment Ohridski." Since 2018, he has been a distance-learning doctoral candidate at the same department. Both the candidate's education and professional experience are closely related to the topic of the dissertation.

2 GENERAL CHARACTERISTICS OF THE DISSERTATION

2.1 Relevance and Significance

In the last few decades, computational technology and information technologies have undergone significant development. This is primarily due to the increase in processing power and miniaturization of devices, transforming them into personal and widely accessible tools. On the other hand, the development of the internet, cloud services, and more recently, artificial intelligence, as well as the analysis of large volumes of data, have turned the IT sector into a leading sector of modern economies. These processes have a tremendous impact on economic development, with clear trends towards increased productivity, improved communication connectivity, job creation, e-commerce, and many others. All of this determines the relevance and significance of the chosen dissertation topic by the candidate. Similar developments in Bulgaria are extremely rare, and the need for them is undeniable.

2.2 Object, Subject, Goals, and Tasks

The main goal of the dissertation is to investigate the characteristics of users and non-users of e-government services in Bulgaria. In connection with the main goal, the candidate also sets a more specific and concrete goal: to study the use of electronic voting machines in Bulgaria, as well as the effect of their introduction on voter turnout and the proportion of uncounted votes. From these two defined goals, two similar but still different subjects of study emerge. Regarding the first goal, the subject of study is internet users in Bulgaria, and regarding the second goal, the subject is the parliamentary elections in Bulgaria in April, July, and November 2021, the European Parliament (EP) elections as well as the local elections in 2019.

In relation to the first goal, the subject of the dissertation is the relationships and dependencies between socio-economic characteristics, the level of skills in information and communication technologies (ICT) of internet users in Bulgaria, and their inclination to use government e-services. Similarly, the subject of the dissertation regarding the second goal is the relationships and dependencies between socio-economic and demographic characteristics, institutional and political characteristics of municipalities, settlements, and polling stations, and different forms of non-participation in elections.

In accordance with the research goals, the candidate formulates five research tasks that determine the structure of the dissertation.

2.3 Methodology and Limitations

All studies in the dissertation utilize generalized Bayesian regression models with varying coefficients at the regional level, with the main difference in the analyses being the data used. While individual-level data is used in the study of e-government services, all analyses related to elections are based on aggregated data at the level of polling stations. The data used in the analyses related to elections in Bulgaria are publicly accessible from the Central Election Commission, the National Statistical Institute, and the Employment Agency.

The candidate defines a limitation regarding the first chapter of the dissertation, which pertains to the design of the study that does not differentiate between the use of e-government services and traditional forms of their use. Furthermore, it is clarified that the analyses of elections in Bulgaria use data aggregated at the level of polling stations, settlements, and municipalities. Therefore, the statistical models do not allow for direct conclusions about the individual behavior of voters.

3 STRUCTURE AND CONTENTS OF THE DISSERTATION

The dissertation consists of 161 pages and is composed of an introduction, six chapters, a conclusion, a bibliography with 174 references, and one appendix. The dissertation includes 30 figures and 30 tables.

The *first chapter* of the dissertation begins with a brief presentation of Bayesian regression models, which are used in the remaining chapters of the study. The exposition introduces multilevel regression models and discusses the choice of prior distributions. The dissertation concludes with a review of the main results, a discussion of the major limitations of the analysis, and suggestions for future research.

The *second chapter* of the dissertation analyzes the propensity of internet users in Bulgaria to use electronic government services in administration, education, and healthcare, using data from a specific survey. The doctoral candidate manages to demonstrate the existence of a division among internet users regarding the use of government e-services, which can be attributed to differences in knowledge and skills in using internet-based services. The contribution of this part of the study is defined by the analyzed relationship between e-service demand and its variation among different demographic groups in the population.

The ***third chapter*** of the dissertation examines the municipal council elections and the two rounds of mayoral elections in 2019, which were the first local elections in Bulgaria where ballot papers allowed voters to explicitly indicate that they did not support any of the candidates (NOTA). The analysis models the variation in three forms of non-participation in elections (non-voting, casting an invalid ballot, or voting for NOTA) depending on institutional, political, socioeconomic, and demographic characteristics at three levels of aggregation: polling station, locality, and municipality. The statistical models reveal evidence of a protest character among some of the invalid ballots.

The ***fourth chapter*** examines the effect of electronic voting machines on the shares of uncounted votes and votes for marginal parties in the European Parliament (EP) elections in 2019 and the parliamentary elections in April 2021. These elections were the first in Bulgaria where a large number of polling stations were equipped with voting machines, and voters could choose between voting with a machine or a paper ballot. In the 2019 EP elections, the allocation of sections with machines was not related to the characteristics of the sections and can be considered a quasi-random experiment. The results of the statistical modeling indicate a decrease in the overall share of uncounted votes in sections with electronic voting machines, but also a higher probability of voting for NPN or marginal parties. Taking into account the difference in votes for marginal parties, the model indicates a strong tendency for the redistribution of votes from invalid ballots to NPN and marginal parties. However, the net effect of electronic voting on support for non-marginal parties remains positive.

The *fifth chapter* examines the extent of the use of electronic voting in the parliamentary elections of 2021 and the EP elections of 2019. These elections are characterized by the voluntary use of electronic voting alongside the option of paper ballot voting. In both elections, only about one-third of voters choose to exercise their right to vote using electronic machines. The doctoral student draws the logical conclusion that this result can be explained by citizens' inertia, who prefer to vote using familiar technology. However, it also raises doubts about the readiness of voters to fully transition to electronic voting, which was practically confirmed in subsequent elections. The proposed analysis of the inclination towards electronic voting by the doctoral student leaves a good impression and contributes to the studies on voting technologies. The author acknowledges that this analysis does not answer the question of whether the transition to electronic voting is associated with a decline in voter turnout, which is at the center of discussions about the future of electronic voting in Bulgaria.

The analysis in the *sixth chapter* uses the observed proportion of voters who voluntarily voted using machines in the April 2021 elections as a measure of voter attitudes towards electronic voting at the local level (polling stations). The difference in voter turnout at the polling station level between the July and November elections is modeled within a two-stage regression model, depending on the proportion of voters who voted using machines in April and control variables describing socio-economic and demographic characteristics at the level of settlements and municipalities. In addition, the model considers the difference in voter turnout as a function of voters' political preferences in the April elections. The main result shows a tendency towards a lower decline in voter turnout in polling stations with a high proportion of electronic voting in April. However, the doctoral student claims that the effect is small and

cannot satisfactorily explain the change in voter turnout, especially compared to sections without electronic voting, where a decline in voter turnout is also observed.

The dissertation concludes with a summary of the main results, a discussion of the limitations of the analyses, and suggestions for future research.

4 *EVALUATION OF THE DISSERTATION WORK AND CONTRIBUTION*

The materials submitted for review by the doctoral student demonstrate a serious and sustained interest in researching the problem. As a result of the author's inquiries, two specific aspects of societal transformation in Bulgaria within the ongoing digital revolution can be distinguished. The *first aspect* concerns the introduction of e-government services and their utilization by internet users in Bulgaria. The quality and functionality of the offered services have been the subject of public discussions, but their demand by users has not been systematically examined, which is an important contribution. The econometric assessments conducted by the doctoral student indicate a strong dependence of the probability of using e-services on individuals' IT skills. Another result of the statistical analysis is the estimation of internet users' inclination towards using e-services in the 28 administrative districts of Bulgaria, taking into account their professional status, skill levels, and education at the individual level. Based on this, conclusions have been formulated, and potential issues for existing users have been identified.

The *second aspect* of digital transformation examines the introduction of electronic voting machines and the recording of election results in Bulgaria during the period 2019-2022. The collected and analyzed information regarding differences in voter turnout shows a tendency towards a lower decline in voter activity in polling stations with a higher proportion of voluntary electronic voting in previous elections. Another significant contribution of the study is the analysis of the selectivity of their usage among different socio-economic and demographic groups, as well as differences in the inclination towards electronic voting based on voters' political preferences.

The doctoral student also addresses the debate for and against mandatory electronic voting in elections, advocating the view that electronic voting would improve the representativeness of elections by eliminating the possibility of blank and erroneous ballots. Special attention is given to the analysis of the nature of invalid voting. It is logical to conclude that areas with a high concentration of educated residents more frequently observe spoiled votes and less frequently encounter invalid ballots. Although the data does not allow for causal relationships to be established, this result is consistent with hypotheses regarding protest voting by educated and politically engaged individuals.

Based on everything presented so far, it can be concluded that the dissertation work, as well as its accompanying publications, contribute to the application of statistical modeling in the following areas:

- Systematic investigation of the propensity to use e-government services in administration, education, and healthcare, depending on socioeconomic characteristics, ICT skills, and experience with internet technologies. It should be emphasized that this represents the first systematic study of the demand for government e-services in Bulgaria.

- Study of the propensity for voter non-participation (non-voting, invalid voting, and voting for non-parliamentary parties) depending on the socio-economic and demographic characteristics of municipalities and localities. In addition, the dissertation work examines the propensity for non-participation depending on institutional and political characteristics at the municipal and polling station levels. This part of the study contributes to the scientific literature in the field of invalid voting and research on voter turnout.

- Investigation of the effect of the presence of electronic voting machines on the propensity for non-voting, invalid voting, voting for non-parliamentary parties, and voting for marginal parties in the 2019 EP elections. In addition, the dissertation work explores the interdependencies between the propensity for these four forms of voting and the cases of voters who used electronic voting machines in the 2019 EP elections and the parliamentary elections in April 2021. This part of the dissertation contributes to research related to the introduction of electronic voting technologies and unconventional voter behavior.

- Study of the propensity to use electronic voting machines in the 2019 EP elections and the parliamentary elections in April 2021, depending on socioeconomic and demographic characteristics measured at the municipal and locality levels. In addition, the dissertation work investigates the effect of past experience with electronic voting on the propensity to vote using a machine. This part of the dissertation contributes to research on the digital transformation of voting technologies.

- Study of differences in voter turnout in the November and July 2021 elections compared to the April 2021 elections, depending on the proportion of voluntary machine voting in April 2021, as well as on the political preferences at the polling station level and the socio-economic and demographic characteristics at the municipal and locality levels. The final part of the dissertation contributes to research on voter turnout and types of voting technologies.

5 OTHER PUBLICATIONS AND PARTICIPATIONS IN SCIENTIFIC FORUMS

1. Amarov, B. and Netov, N. (2022) Usage of electronic public services in Bulgaria, Journal of International Business Research and Marketing, 7, pp. 36–41. Available at: https://doi.org/10.18775/jibrm.1849-8558.2015.73.3004.

2. Amarov, B. and Netov, N. (2023) Usage of electronic education services in Bulgaria, International Journal of Management Science and Business Administration, 9(2), pp. 30–36. Available at: https://doi.org/10.18775/ijmsba.1849-5664-5419.2014.92.1003.

3. Amarov, B. (2023) Electronic Voting Machines and Turnout in the Bulgarian 2021 Parliamentary Elections, in Societal Transformations and Sustainable Development with Respect to Environment in the Post COVID-19 Digital Era. First Annual Transform4Europe PhD Conference, 8-9 December 2021, Sofia, Bulgaria: St. Kliment Ohridski University Press, pp. 41–48.

4. Amarov, B. (2021a) Adoption of electronic voting machines in the Bulgarian 2021 parliamentary elections. In: the twenty-second faculty of economics and business administration, Sofia University "St. Kliment Ohridski" annual conference: 'Environmental, social and governance challenges for recovery and resilience', November 26-27, 2021.

5. Amarov, B. (2021b) Electronic voting machines and turnout in the Bulgarian 2021 parliamentary elections, in Societal transformations and sustainable development with respect to environment in the post COVID-19 digital era. 8th-9th December 2021.

6. Amarov, B. and Netoff, N. (2022a) 'Usage of electronic education services in Bulgaria', in 87th international scientific conference on economic and social development. Svistov, Bulgaria.

7. Amarov, B. and Netoff, N. (2022b) 'Usage of electronic public services in Bulgaria', in 87th international scientific conference on economic and social development. Svistov.

8. Amarov, B. (2021) 'Multilevel modeling of invalid voting rates in the Bulgarian local elections 2015 and 2019', in Applied modeling in economics, finance and social sciences, 28 June 28 - July 2, 2021. Sozopol, Bulgaria.

6   COMPLIANCE OF THE CANDIDATE'S PROVIDED PUBLICATIONS AND OTHER DOCUMENTS WITH THE LEGAL REQUIREMENTS FOR OBTAINING THE ACADEMIC AND EDUCATIONAL DEGREE OF "DOCTOR."

The main regulatory requirements for obtaining the academic and educational degree of "Doctor" are as follows:

• Law on the Development of the Academic Staff in the Republic of Bulgaria, Article 6(3) - "The dissertation work under paragraph 2 must contain scientific or scientifically applied results that represent an original contribution to science. The dissertation work must demonstrate that the candidate possesses in-depth theoretical knowledge in the respective specialty and abilities for independent scientific research."

• Regulation on the Conditions and Procedure for Acquiring Scientific Degrees and Holding Academic Positions at Sofia University "St. Kliment Ohridski," Article 66(1) - "The dissertation work is a composition that contains scientific or scientifically applied results with an original contribution to science and demonstrates that the candidate has in-depth theoretical knowledge in the respective specialty and abilities for independent scientific research."

Based on the description of the dissertation work and the review of its main contributory points, I can confirm that Boyko Amarov's dissertation work categorically demonstrates that he possesses in-depth theoretical knowledge and indisputable skills for successfully conducting independent scientific research. The presented doctoral dissertation contains scientific and scientifically applied results that represent an original contribution, which is also confirmed by the candidate's publications on the topic of the dissertation research.

7   CONCLUSION

The overall impression of the dissertation work is positive. It is evident that the candidate has familiarized himself with a wide range of literary sources and demonstrates good knowledge of the subject matter. The subject and object of the research are clearly presented, allowing for the formulation of the author's thesis, which is substantiated through the establishment of specific goals and objectives. The structure of the exposition follows a clear logic, and the style of presentation skillfully combines academic rigor with simplicity of expression and ease of comprehension. The candidate also demonstrates a high level of both

theoretical and practical-applied knowledge and skills in the field of statistical and econometric analysis.

Based on the achieved results and the arguments presented above, I believe that the proposed dissertation work by the candidate, as well as the accompanying publications, fully meet the criteria and requirements laid down in the Regulation for the Application of the Law on the Development of the Academic Staff in the Republic of Bulgaria and the Regulation on the Conditions and Procedure for Acquiring Scientific Degrees and Holding Academic Positions at Sofia University "St. Kliment Ohridski." With this opinion, I express my positive view on the awarding of the academic degree of "Doctor" to Boyko Amarov.

June 14, 2023

Prof. (Assoc.) Victor Yotzov, PhD