FEDERAL STATE BUDGET EDUCATIONAL INSTITUTION OF HIGHER EDUCATION "LOMONOSOV MOSCOW STATE UNIVERSITY"

FACULTY OF ECONOMICS

«APPROVED»

Dean of the Faculty of Economics, MSU

professor _____ A.A.Auzan

«___» _____2024

COURSE SYLLABUS

Course title:

Applied Bayesian Statistics

Level of higher education:

MASTER STUDIES

Field of study:

38.04.01. ECONOMICS

Mode of study:

FULL-TIME

Course syllabus is considered and approved by
the Educational and Methodological Council of the Faculty of Economics
(minutes №_____, date)

Moscow 2024

The course syllabus is developed in accordance with the self-established MSU educational standard (ES MSU) for implemented main professional educational programs of higher education for Master's degree in the field of study 38.04.01. Economics

ES MSU is approved by the decision of MSU Academic Council dated December 28, 2020, minutes №7

Year (years) of enrollment: 2024 and forthcoming

1. **Place and status of the course in the structure of the Master program**

Course status: *elective*

Trimester: 4

2. **Course Prerequisites**

This discipline is based on the knowledge and skills acquired as a result of studying following courses:

— English
— Econometrics (advanced level)
— Machine Learning and Data Analysis – 1

3. **Intended learning outcomes (ILO) of the course associated to the required competencies of the graduates**

Competencies of graduates (codes)	**Indicators of achievement of competencies**	**Intended learning outcomes of the course (module) associated to the required competencies of the graduates**
МПК-4. Способен видеть логические связи в системе собранной, обработанной и проанализированной информации, и на основании этого разрабатывать рекомендации для лиц, принимающих решения на микро- и макро уровне, или бизнес-решения	МПК-4.И-1. Анализирует и систематизирует собранные данные, разрабатывает рекомендации для лиц, принимающих решения на основе собранных данных	МПК-4.И-1.У-1. Умеет строить логические взаимосвязи в системе собранной информации МПК-4.И-1.У-2. Умеет разрабатывать рекомендации для лиц, принимающих управленческие решения как сфере государственного управления на разных уровнях, так и в сфере бизнеса
ОПК-5. Способен использовать современные информационные технологии и программные средства при решении профессиональных задач	ОПК-5.И-1. Применяет общие или специализированные пакеты прикладных программ, предназначенные для обработки, визуализации и анализа данных, в том числе эконометрического анализа и имитационного моделирования	ОПК-5.И-1.У-1. Умеет применять общие или специализированные пакеты прикладных программ (MS Excel, Eviews, Stata, SPSS, AnyLogic, Tableau и др.) или языки программирования (R, Python и др.), предназначенные для обработки, визуализации и анализа данных, в том числе эконометрического анализа и имитационного моделирования в, в соответствии со своими профессиональными задачами

4. **Workload of the course by types of activity**

The workload of the discipline is 3 ECTS: 108 academic hours, including 52 academic hours of contact work with a professor, 56 academic hours of self-directed studies.

5. **Learning format:** full-time, with the use of educational platform On.Econ (use of distant learning technologies is allowed if necessary)

6. **Content of the course structured by topics (sections) indicating the number of academic hours allocated to them and types of training**

Title and brief content of sections	**Total**, hours	**Including**		
		Contact work (work in contact with a professor)		**Student self-directed studies**, hours
		Seminars, hours	Group consultations, hours	
Topic 1. Bayesian statistics for business and principles of modelling	32	8	8	16
Topic 2. Bayesian ABCDE-testing and parameter recovery	20	4	4	12
Topic 3. Bayesian inference debugging	20	4	4	12
Topic 4. Bayesian time series and Gaussian processes	32	8	8	16
Midterm assessment:	4			
Total	**108**			56

Brief content of the course topics

Topic 1. Bayesian statistics for business and principles of modelling

Bayesian approach in statistics vs frequency approach in econometrics. Bayes formula. Принцип достаточности и принцип правдоподобия. Примеры задач, решаемых в рамках байесовского подхода. Introduction to PyMC: environment settings. Basic model. Parametrization, prior distribution choice. Prior distribution testing. HMC in action. Bayesian hierarchy. Adaptation matrix. Yandex DataSphere service, practice case solution using cloud.

Recommended core literature:

1. Gelman et al. (2020) Bayesian workflow. Электронный ресурс, URL: https://arxiv.org/abs/2011.01808

Recommended additional literature:

1. https://www.pymc.io/projects/docs/en/latest/installation.html — PyMC user guide
2. https://camdavidsonpilon.github.io/Probabilistic-Programming-and-Bayesian-Methods-for-Hackers/ — Introduction to Bayesian methods and probabilistic programming
3. https://www.pymc.io/projects/docs/en/stable/learn.html — PyMC for Bayesian modelling

Topic 2. Bayesian ABCDE-testing and parameter recovery

Bayesian ABCDE-tests. Parameter Recovery: application cases, algorithm. Introduction to Dask. Effective Xarray.

Recommended core literature:

1. Gelman et al. (2020) Bayesian workflow. Электронный ресурс, URL: https://arxiv.org/abs/2011.01808
2. Dube, Jean-Pierre, Gunter Hitsch and Peter Rossi (2012), State dependence and alternative explanations for consumer inertia, RAND Journal of Economics Vol. 41, No. 3, Autumn 2010 pp. 417445
3. Martin O. Bayesian Analysis with Python - Second Edition. 2018. – 356 pp. ISBN 9781789341652 https://www.packtpub.com/product/bayesian-analysis-with-python/9781789341652

Recommended additional literature:

1. https://www.pymc.io/projects/docs/en/latest/installation.html — PyMC user guide
2. https://camdavidsonpilon.github.io/Probabilistic-Programming-and-Bayesian-Methods-for-Hackers/ — Introduction to Bayesian methods and probabilistic programming
3. https://www.pymc.io/projects/docs/en/stable/learn.html — PyMC for Bayesian modelling

Topic 3. Bayesian inference debugging

HMC computation problems: practice and tools overview. HMC debugging algorithm. Practice case solution using Yandex cloud.

Recommended core literature:

1. Gelman et al. (2020) Bayesian workflow. Электронный ресурс, URL: https://arxiv.org/abs/2011.01808
2. Martin O. Bayesian Analysis with Python - Second Edition. 2018. – 356 pp. ISBN 9781789341652 https://www.packtpub.com/product/bayesian-analysis-with-python/9781789341652

Recommended additional literature:

1. Salvatier J, et al. (2016) Probabilistic programming in Python using PyMC3, URL: https://www.pymc.io/projects/docs/en/latest/learn/core_notebooks/pymc_overview.html
2. https://www.pymc.io/projects/docs/en/latest/installation.html — PyMC user guide
3. https://camdavidsonpilon.github.io/Probabilistic-Programming-and-Bayesian-Methods-for-Hackers/ — Introduction to Bayesian methods and probabilistic programming
4. https://www.pymc.io/projects/docs/en/stable/learn.html — PyMC for Bayesian modelling

Topic 4. Bayesian time series and Gaussian processes

Introduction to Gaussian processes. Core hyperparameters. Разбор примера. Prior predictive for Gaussian processes. Effective parametrization. Trends and seasonality, control variables. Cross-validation. Time series practice case: model with trend, model with trend and seasonality. Using LOO for model selection. Forecasts. Time-series practice case solution using Yandex cloud.

Recommended core literature:

1. Gelman et al. (2020) Bayesian workflow. Электронный ресурс, URL: https://arxiv.org/abs/2011.01808
2. Martin O. Bayesian Analysis with Python - Second Edition. 2018. – 356 pp. ISBN 9781789341652 https://www.packtpub.com/product/bayesian-analysis-with-python/9781789341652

Recommended additional literature:

1. Salvatier J, et al. (2016) Probabilistic programming in Python using PyMC3, URL: https://www.pymc.io/projects/docs/en/latest/learn/core_notebooks/pymc_overview.html
2. https://www.pymc.io/projects/docs/en/stable/learn.html — PyMC for Bayesian modelling
3. Robert C. P. et al. The Bayesian choice: from decision-theoretic foundations to computational implementation. – New York : Springer, 2007. – T. 2.
4. Rossi, P.E., G.M. Allenby and R. McCulloch (2005) Bayesian Statistics and Marketing, John Wiley & Sons, Ltd.

7. Assessment tools to assess the course learning outcomes

7.1. Sample assessment tools:

Learning outcomes of the course	Types of assessment tools
МПК-4.И-1.У-1. Умеет строить логические взаимосвязи в системе собранной информации МПК-4.И-1.У-2. Умеет разрабатывать рекомендации для лиц, принимающих управленческие решения как сфере государственного управления на разных уровнях, так и в сфере бизнеса	Home assignment Project assignment Midterm assessment (project presentation)
ОПК-5.И-1.У-1. Умеет применять общие или специализированные пакеты прикладных программ (MS Excel, Eviews, Stata, SPSS, AnyLogic, Tableau и др.) или языки программирования (R, Python и др.), предназначенные для обработки, визуализации и анализа данных, в том числе эконометрического анализа и имитационного моделирования в, в соответствии со своими профессиональными задачами	Home assignment Project assignment

7.2. Course assessment criteria (scores):

Types of assessment tools	Score
Home assignment	90
Project assignment	30
Midterm assessment (project presentation)	30
Total	**150**

7.3. Grade for the course is determined based on the following criteria:

Grade	Minimum score	Maximum score
Excellent	127,5	150,0
Good	97,5	127,0
Satisfactory	60,0	97,0
Failed	0,0	59,5

Note: in case a student's score obtained during the trimester is less than 20% of the maximum score of the discipline, the following rule of passing the course should be applied at the midterm assessment (and further re-examination): 'a student can obtain only a satisfactory mark and only in case she/he receives for the midterm assessment, including all the course material, no less than 85% of the score allocated to this assessment'.

7.4. Typical tasks and other materials necessary to assess the learning outcomes:

Example of home assignment.
The data used is in the price.csv file. Select the resulting metric. Regarding empirical distribution for indicators, check with appropriate tests that it is statistically different from normal. Based on the result, conduct tests for comparing the means in 2 groups for the selected metric. Write a short report with the final decision for the pricing policy of company N. Submit this work in the Jupiter Notebook.

Example of project assignment.
The project is a short text (up to 15 pages) containing a statement of the problem, a brief review of the literature, an analysis of the theoretical model (or models) with premises and conclusions, as well as a selection of examples from empirical articles illustrating the conclusions of the model and own calculations. Selection of data and their description is required. Training data should be taken from open sources.
The task is performed in groups (of 2-3) or individually.
Submit this work in the Jupiter Notebook. Yandex DataSphere service is recommended.

After the project is submitted, it is cross reviewed. A review of the project by colleagues and an oral presentation with it (questions, remarks, comments) is expected.

7.5. Methodological guidelines and assignment requirements:

Home assignments *are practical tasks aimed at consolidating the skills of machine learning and data analysis in Python within various topics. The task is submitted in the Jupyter-notebook .ipynb format with the code, comments and answers to the questions of the task. The comments should describe the methods and data used to solve the problem, justify the choice of the algorithm in detail, and present the results of calculations (using tables and figures if necessary). Homework allows you to score up to 90 points.*

Project assignments *are practical tasks that require the student to apply the acquired machine learning skills to solve problems. The task is given in the format of an oral presentation, as well as the source code in Python in a convenient format (for example, Jupyter laptop, code on the Github repository, zip archive). The project can be presented both individually and in a team. During the presentaion of the project, it is required to briefly describe the problem being solved, describe the methods of machine learning and data analysis used, formulate and explain the results obtained, answer the questions of the host.*

8. Resources

8.1. List of main and additional literature

Recommended core literature:

1. Gelman et al. (2020) Bayesian workflow. Электронный ресурс, URL: https://arxiv.org/abs/2011.01808
2. Dube, Jean-Pierre, Gunter Hitsch and Peter Rossi (2012), State dependence and alternative explanations for consumer inertia, RAND Journal of Economics Vol. 41, No. 3, Autumn 2010 pp. 417445
3. Martin O. Bayesian Analysis with Python - Second Edition. 2018. – 356 pp. ISBN 9781789341652 https://www.packtpub.com/product/bayesian-analysis-with-python/9781789341652

Recommended additional literature:

1. Salvatier J, et al. (2016) Probabilistic programming in Python using PyMC3, URL:

https://www.pymc.io/projects/docs/en/latest/learn/core_notebooks/pymc_overview.html
2. Robert C. P. et al. The Bayesian choice: from decision-theoretic foundations to computational implementation. – New York : Springer, 2007. – T. 2.
3. Rossi, P.E., G.M. Allenby and R. McCulloch (2005) Bayesian Statistics and Marketing, John Wiley & Sons, Ltd.

8.2. List of licensed software

- Anaconda (Python distribution)
- Data-science packages for Python programming language
- Yandex Cloud, Yandex DataSphere.

8.3. List of professional databases and information referral systems

-

8.4. List of Internet resources (if necessary)

1. https://www.pymc.io/projects/docs/en/latest/installation.html — PyMC user guide
4. https://camdavidsonpilon.github.io/Probabilistic-Programming-and-Bayesian-Methods-for-Hackers/ — Introduction to Bayesian methods and probabilistic programming
2. https://www.pymc.io/projects/docs/en/stable/learn.html — PyMC for Bayesian modelling
3. https://www.nber.org/lecture/summer-institute-2007-methods-lecture-bayesian-inference — Imbens G., J.M. Wooldridge (2007) Lecture Notes for NBER Summer School: Bayesian Inference

8.5. Description of material and technical support

To organize classes in the discipline the following technical training tools are needed: a computer class with a projector and a blackboard.

9. **Language of instruction:** *English*

10. **Professor (professors):** PyMC labs partner M. Kochurov (М.В. Кочуров)

11. **Syllabus authors:** PyMC labs partner M. Kochurov (М.В. Кочуров)