Indian Institute of Technology Kanpur

Proposal for a New Course

1. Course No: **ECO703**

2. Course Title: **Statistical Methods**

3. Per Week Lectures: <u>3</u> (L), Tutorial: <u>0</u> (T), Laboratory: <u>0</u> (P), Additional Hours [0-2]: <u>0</u> (A), Credits (3*L+0*T+0*P+0*A): **9 Credits**

4. Duration of Course: Full Semester

5. Proposing Department/IDP: Economic Sciences

   Other Departments/IDPs which may be interested: None

   Other faculty members interested in teaching the proposed course: -

6. Proposing Instructor(s): **Faculty members of Economic Sciences department**

7. **Course Description:**

A) Objectives:

This course provides a rigorous introduction to probability theory and mathematical statistics. The objective is to equip students with a solid mathematical foundation in probability and statistical inference essential for advanced research and data-driven applications across disciplines. Upon completion, students will be able to apply probability theory to model uncertainty in complex systems, derive properties of estimators including bias, variance, and asymptotic distributions, and construct and interpret hypothesis tests and confidence intervals. Students will also develop a thorough understanding of the theoretical foundations underlying modern inferential methods, gain hands-on familiarity with simulation-based techniques including bootstrap and MCMC, and be prepared to critically engage with methodological literature in leading academic journals.

B) Contents:

S. No	Broad Title	Topics	No. of Lectures*
Part A: Probability Theory			
1.	Basic Probability Theory	Sample spaces and events. Probability Kolmogorov axioms and properties. Conditional probability. Independence. Bayes' theorem. ***Possible Applications:*** *Wage and education distributions; stock market returns; recession probabilities.*	3
2.	Random Variables and expectation	Distribution and density functions, key discrete and continuous distributions. Bivariate, multivariate, and conditional distributions and expectations. Transformations and moment generating functions. Expected values, variance, covariance, and related inequalities. ***Possible Applications:*** *Modeling unemployment duration; income and wealth distributions; asset returns, Wage-education relationships; portfolio risk; law of iterated expectations in*	6

		forecasting	
3.	Convergence of Random Variables	Types of convergence. The Law of Large Numbers. The Central Limit Theorem. The Delta method. ***Possible Applications***: *Consistency of sample averages; asymptotic approximations for economic estimators.*	4

Part B: Statistical Theory

4.	Sampling, Models and Estimation	Random samples, estimators, and their sampling distributions, bias, variance, mean squared error, and best unbiased estimators, standard errors and the chi-square, t, and F distributions arising from normal samples. Parametric and nonparametric models. The empirical distribution function. Statistical functionals and plug-in estimators. Bootstrap principle: variance estimation and confidence intervals (normal, pivotal, and percentile). ***Possible Applications:*** *Estimating average treatment effects; wage gaps; returns to education, Gini coefficient; poverty rates; quantiles of income distribution, standard errors for inequality measures, inference with small samples in labor economics*	7
5.	Parametric inference: MLE and method of moments	The likelihood function and maximum likelihood estimation, properties of MLEs including consistency, asymptotic normality, optimality, Fisher information, and behavior under model misspecification, multiparameter models and Kullback–Leibler divergence. Method of moments: moment estimators, smooth functions of moments, parametric moment estimation, and generalized method of moments. ***Possible Applications:*** *Discrete choice models; duration models for unemployment spells.*	5
6.	Parametric inference: Hypothesis Testing and confidence intervals	The Wald test. p-values and their interpretation. The likelihood ratio test. Permutation tests. Multiple testing. Confidence interval construction, confidence intervals for mean and variance, asymptotic confidence intervals, interpretation and use ***Possible Applications:*** *Testing economic hypotheses; policy evaluation; specification testing*	5
7.	Statistical Decision Theory	Decision theoretic framework, Loss and risk functions. Bayes and minimax estimators. Admissibility. Stein's paradox and shrinkage. ***Possible Applications:*** *Forecasting with many predictors; regularization in high-dimensional settings.*	3
8	Simulation Methods	Monte Carlo integration. Importance sampling. Introduction to MCMC: Metropolis-Hastings algorithm ***Possible Applications:*** *Evaluating estimator performance; Bayesian computation in macroeconometrics.*	4
9.	Nonparametric Density Estimation	The bias-variance tradeoff. Histograms. Kernel density estimation. Bandwidth selection. ***Possible Applications:*** *Estimating wage densities; income and wealth distributions; earnings mobility.*	2

*50-minute lecture each, total of 39 lectures

C) Pre-requisites: None

D) Short summary for Courses of Study Booklet:

"This course covers probability theory and mathematical statistics at the postgraduate level. Topics include probability foundations, random variables and distributions, convergence concepts, sampling theory, maximum likelihood and method of moments estimation, hypothesis testing, confidence intervals, simulation-based inference, and nonparametric density estimation. The course provides essential preparation for advanced work in statistical modeling, inference, and data analysis across disciplines."

8. Recommended Books:

- Hansen, Bruce E. Probability and Statistics for Economists. Princeton University Press, 2022.
- Wasserman, L. All of Statistics: A Concise Course in Statistical Inference, Springer.
- Casella, George, and Roger L. Berger. Statistical Inference. 2nd Edition, Cengage Learning, 2002.
- Stachurski, John. A Primer in Econometric Theory. MIT Press, 2016.

Dated: _____   Proposer: _____

Dated: _____   DUGC/DPGC Convener: _____

The course is approved / not approved

Chairman, SUGC/SPGC

Dated: