The Economics-Statistics major provides the student with a grounding in economic theory comparable to that provided by the general economics major; and also exposes the student to rigorous and extensive training in Statistics. Students choose between two tracks of the major. The Computational Track consists of coursework in applied statistical methods. It is recommended for students preparing to apply statistical methods in the social sciences. The Theoretical Track consists of calculus-based probability, and the theory of statistical inference. It also provides some practical training in data analysis.

Available to students of the Class of 2021 and later.

Department Administrator: Robert O'Connor

Chair: Rajiv Sethi (Ann Whitney Olin Professor)

Professors: Elizabeth Ananat, André Burgstaller, Alan Dye, Daniel Hamermesh (Distinguished Scholar), Sharon Harrison, Shaw-Hwa Lo (Statistics), Lalith Munasinghe, David Weiman (Alena Wels Hirschorn ’58 Professor)

Associate Professors: Yang Feng (Statistics), Jingchen Liu (Statistics), Randall Rebach, Ashley Timmer (Adjunct)

Assistant Professors: Belinda Archibong, Biwei Chen (Term), Martina Jasova, Elizabeth Kopko (Adjunct), Peter Orbanz (Statistics), Sonia Pereira (Term), Anja Tolonen, Homa Zarghamee

Associates: John Park

Lecturers in Statistics: Banu Baydil, Ronald Neath, David Rios, Joyce Robbins, Gabriel Young

### Computational Track

A major in Economics-Statistics, Computational Track must complete the following 16 courses or their equivalents:

**10 courses in Economics, Mathematics**

- **ECON BC1003** Introduction to Economic Reasoning
- **MATH UN1102** Calculus II
- **MATH UN1201** Calculus III
- **MATH UN2010** Linear Algebra
- **ECON BC3033** Intermediate Macroeconomic Theory
- **ECON BC3035** Intermediate Microeconomic Theory
- **ECON BC3041** Theoretical Foundations of Political Economy

Two Upper-level Electives in Economics

- **ECON BC3063** Senior Seminar

**6 courses in Statistics**

- **STAT UN1201** Calculus-Based Introduction to Statistics
- **ECON BC3018** Econometrics
- **STAT UN2102** Applied Statistical Computing
- **STAT UN2104** Applied Categorical Data Analysis

One of the following two courses:

- **STAT UN3105** Applied Statistical Methods
- **STAT UN3106** Applied Data Mining

One Upper-level Elective in Statistics (STAT UN3106, GU4203, GU4204, GU4205, GU4206, or a Computer Science Elective)

### Theoretical Track

A major in Economics-Statistics, Theoretical Track must complete the following 16 courses or their equivalents:

**10 courses in Economics, Mathematics** which are the same as in the Computational Track above, plus

**6 courses in Statistics** which differs from the Computational Track somewhat:

- **STAT UN1201** Calculus-Based Introduction to Statistics
- **ECON BC3018** Econometrics
- **STAT GU4203** PROBABILITY THEORY
- **STAT GU4204** Statistical Inference
- **STAT GU4205** Linear Regression Models

One Elective in Statistics at the 3000+ level (or a Computer Science Elective such as COMS W1004, W1005, W1007, or STAT UN2102)

### Economics, Mathematics

**ECON BC1003 Introduction to Economic Reasoning. 3 points.**


Covers basic elements of microeconomic and macroeconomic reasoning at an introductory level. Topics include Individual Constraints and Preferences, Production by Firms, Market Transactions, Competition, The Distribution of Income, Technological Progress and Growth, Unemployment and Inflation, the Role of Government in the Economy.

Note: Students cannot get credit for ECON BC1003 if they have taken the Columbia introductory course ECON W1105 Principles of Economics.

#### Fall 2020: ECON BC1003

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECON 1003</td>
<td>002/00251</td>
<td>T Th 2:40pm - 3:55pm Room TBA</td>
<td>Homa Zarghamee</td>
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<td>30/30</td>
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<tr>
<td>ECON 1003</td>
<td>003/00252</td>
<td>T Th 10:10am - 11:25am Room TBA</td>
<td>Belinda Archibong</td>
<td>3</td>
<td>38/30</td>
</tr>
</tbody>
</table>

**MATH UN1102 Calculus II. 3 points.**

Prerequisites: MATH UN101 or the equivalent.

Methods of integration, applications of the integral, Taylor’s theorem, infinite series. (SC)

#### Fall 2020: MATH UN1102

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
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<tr>
<td>MATH 1102</td>
<td>001/11302</td>
<td>M W 11:40am - 12:55pm Online Only</td>
<td>Maithreya Sitaraman</td>
<td>3</td>
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<tr>
<td>MATH 1102</td>
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<td>Zachary Sylvan</td>
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<td>MATH 1102</td>
<td>003/11304</td>
<td>M W 4:10pm - 5:25pm Online Only</td>
<td>Zachary Sylvan</td>
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<tr>
<td>MATH 1102</td>
<td>005/00434</td>
<td>T Th 2:40pm - 3:55pm Room TBA</td>
<td>Lindsay Piechick</td>
<td>3</td>
<td>43/100</td>
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<tr>
<td>MATH 1102</td>
<td>006/11306</td>
<td>T Th 6:10pm - 7:25pm Online Only</td>
<td>Elliott Stein</td>
<td>3</td>
<td>21/45</td>
</tr>
<tr>
<td>MATH 1102</td>
<td>007/21402</td>
<td>T Th 11:40am - 12:55pm Online Only</td>
<td>Renata Picciotto</td>
<td>3</td>
<td>9/30</td>
</tr>
</tbody>
</table>
MATH UN1201 Calculus III. 3 points.
Prerequisites: MATH UN1101 or the equivalent
Vectors in dimensions 2 and 3, complex numbers and the complex exponential function with applications to differential equations, Cramer’s rule, vector-valued functions of one variable, scalar-valued functions of several variables, partial derivatives, gradients, surfaces, optimization, the method of Lagrange multipliers. (SC)

MATH UN2010 Linear Algebra. 3 points.
Prerequisites: MATH UN1201 or the equivalent
Matrices, vector spaces, linear transformations, eigenvalues and eigenvectors, canonical forms, applications. (SC)

ECON BC3035 Intermediate Microeconomic Theory. 4 points.
Prerequisites: An introductory course in microeconomics or a combined macro/micro principles course (ECON BC1003 or ECON W1105, or the equivalent) and one semester of calculus or ECON BC1007, or permission of the instructor.
Preferences and demand; production, cost, and supply; behavior of markets in partial equilibrium; resource allocation in general equilibrium; pricing of goods and services under alternative market structures; implications of individual decision-making for labor supply; income distribution, welfare, and public policy. Emphasis on problem solving.

ECON BC3041 Theoretical Foundations of Political Economy. 3 points.
Prerequisites: An introductory course in economics or permission of the instructor.
Intellectual origins of the main schools of thought in political economy. Study of the founding texts in classical political economy, Marxian economics, neoclassicism, and Keynesianism.

ECON BC3063 Senior Seminar. 4 points.
Prerequisites: Permission of the instructor and the completion of all courses (except for the senior requirement) required for the economics track, political economy track, or economics and mathematics majors. Exceptions to these prerequisites may be granted by the chair of the department only. Seminar sections are limited to 15 students. A topic in economic theory or policy of the instructor’s choice. See department for current topics and for senior requirement preference forms.
### Statistics, Computer Science

**STAT UN1201 Calculus-Based Introduction to Statistics. 3 points.**

Prerequisites: one semester of calculus. Designed for students who desire a strong grounding in statistical concepts with a greater degree of mathematical rigor than in STAT W1111. Random variables, probability distributions, pdf, cdf, mean, variance, correlation, conditional distribution, conditional mean and conditional variance, law of iterated expectations, normal, chi-square, F and t distributions, law of large numbers, central limit theorem, parameter estimation, unbiasedness, consistency, efficiency, hypothesis testing, p-value, confidence intervals, maximum likelihood estimation. Serves as the prerequisite for ECON W3412.

<table>
<thead>
<tr>
<th>Fall 2020: STAT UN1201</th>
<th>Course</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
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<tbody>
<tr>
<td>STAT 1201</td>
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<td>M W 11:40am - 12:55pm</td>
<td>Online Only</td>
<td>David Rios</td>
<td>3</td>
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<tr>
<td>STAT 1201</td>
<td>002/12845</td>
<td>T Th 11:40am - 12:55pm</td>
<td>Online Only</td>
<td>Joyce Robbins</td>
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<td>86/86</td>
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<tr>
<td>STAT 1201</td>
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<td>Online Only</td>
<td>Carsten Chong</td>
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<td>86/86</td>
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<td>STAT 1201</td>
<td>004/12847</td>
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<td>Online Only</td>
<td>Arian Maleki</td>
<td>3</td>
<td>86/86</td>
</tr>
</tbody>
</table>

**ECON BC3018 Econometrics. 4 points.**
Prerequisites: ECON BC3033 or ECON BC3035, and ECON BC2411 or STAT W1111 or STAT W1211, or permission of the instructor. Prerequisites: ECON BC3033 or ECON BC3035, and ECON BC2411 or STAT W1111 or STAT W1211, or permission of the instructor. Specification, estimation and evaluation of economic relationships using economic theory, data, and statistical inference; testable implications of economic theories; econometric analysis of topics such as consumption, investment, wages and unemployment, and financial markets.

<table>
<thead>
<tr>
<th>Fall 2020: ECON BC3018</th>
<th>Course</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
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<tbody>
<tr>
<td>ECON 3018</td>
<td>001/00263</td>
<td>M T W Th 1:10pm - 2:25pm</td>
<td>Room TBA</td>
<td>Daniel Hamermesh</td>
<td>4</td>
<td>47/48</td>
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</table>

**STAT UN2102 Applied Statistical Computing. 3 points.**
Corequisites: An introductory course in statistic (STAT UN1101 is recommended). This course is an introduction to R programming. After learning basic programming component, such as defining variables and vectors, and learning different data structures in R, students will, via project-based assignments, study more advanced topics, such as recursion, conditionals, modular programming, and data visualization. Students will also learn the fundamental concepts in computational complexity, and will practice writing reports based on their statistical analyses.

<table>
<thead>
<tr>
<th>Fall 2020: STAT UN2104</th>
<th>Course</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAT 2104</td>
<td>001/12473</td>
<td>M W 10:10am - 11:25am</td>
<td>Online Only</td>
<td>Shau-Hwa Lo</td>
<td>3</td>
<td>20/50</td>
</tr>
<tr>
<td>STAT 2104</td>
<td>003/12474</td>
<td>T Th 6:10pm - 7:25pm</td>
<td>Online Only</td>
<td>Cristian Pasarica</td>
<td>3</td>
<td>45/60</td>
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<tr>
<td>STAT 2104</td>
<td>004/12366</td>
<td>T Th 6:10pm - 7:25pm</td>
<td>Online Only</td>
<td>Cristian Pasarica</td>
<td>3</td>
<td>25/80</td>
</tr>
</tbody>
</table>

**STAT UN2104 Applied Categorical Data Analysis. 3 points.**
Prerequisites: STAT UN2103 is strongly recommended. Students without programming experience in R might find STAT UN2102 very helpful. This course covers statistical models and methods for analyzing and drawing inferences for problems involving categorical data. The goals are familiarity and understanding of a substantial and integrated body of statistical methods that are used for such problems, experience in analyzing data using these methods, and proficiency in communicating the results of such methods, and the ability to critically evaluate the use of such methods. Topics include binomial proportions, two-way and three-way contingency tables, logistic regression, log-linear models for large multi-way contingency tables, graphical methods. The statistical package R will be used.

**STAT UN3105 Applied Statistical Methods. 3 points.**
Prerequisites: At least one, and preferably both, of STAT UN2103 and UN2104 are strongly recommended. Students without programming experience in R might find STAT UN2102 very helpful. This course is intended to give students practical experience with statistical methods beyond linear regression and categorical data analysis. The focus will be on understanding the uses and limitations of models, not the mathematical foundations for the methods. Topics that may be covered include random and mixed-effects models, classical non-parametric techniques, the statistical theory causality, sample survey design, multi-level models, generalized linear regression, generalized estimating equations and over-dispersion, survival analysis including the Kaplan-Meier estimator, log-rank statistics, and the Cox proportional hazards regression model. Power calculations and proposal and report writing will be discussed.

**ECON W3412**
Econometrics.

**STAT UN3106 Applied Data Mining. 3 points.**
Prerequisites: STAT UN2103. Students without programming experience in R might find STAT UN2102 very helpful. This course will be taught as a machine learning class. We will cover topics including data-based prediction, classification, specific classification methods (such as logistic regression and random forests), and basics of neural networks. Programming in homeworks will be required. Students without programming experience in R might find STAT UN2102 helpful.

**STAT GU4203 PROBABILITY THEORY. 3 points.**
Prerequisites: At least one semester, and preferably two, of calculus. An introductory course (STAT UN2101, preferably) is strongly recommended. A calculus-based introduction to probability theory. A quick review of multivariate calculus is provided. Topics covered include random variables, conditional probability, expectation, independence, Bayes’ rule, important distributions, joint distributions, moment generating functions, central limit theorem, laws of large numbers and Markov’s inequality.

<table>
<thead>
<tr>
<th>Fall 2020: STAT GU4203</th>
<th>Course</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
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</thead>
<tbody>
<tr>
<td>STAT 4203</td>
<td>001/12473</td>
<td>M W 10:10am - 11:25am</td>
<td>Online Only</td>
<td>Shau-Hwa Lo</td>
<td>3</td>
<td>20/50</td>
</tr>
<tr>
<td>STAT 4203</td>
<td>003/12474</td>
<td>T Th 6:10pm - 7:25pm</td>
<td>Online Only</td>
<td>Cristian Pasarica</td>
<td>3</td>
<td>45/60</td>
</tr>
<tr>
<td>STAT 4203</td>
<td>004/12366</td>
<td>T Th 6:10pm - 7:25pm</td>
<td>Online Only</td>
<td>Cristian Pasarica</td>
<td>3</td>
<td>25/80</td>
</tr>
</tbody>
</table>
STAT GU4204 Statistical Inference. 3 points.

Prerequisites: STAT GU4203. At least one semester of calculus is required; two or three semesters are strongly recommended. Calculus-based introduction to the theory of statistics. Useful distributions, law of large numbers and central limit theorem, point estimation, hypothesis testing, confidence intervals maximum likelihood, likelihood ratio tests, nonparametric procedures, theory of least squares and analysis of variance.

Fall 2020: STAT GU4204
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
STAT 4204  003/12477  M W 6:10pm - 7:25pm  Online Only  Irene Hueter  3  54/60
STAT 4204  004/12475  M W 6:10pm - 7:25pm  Online Only  Irene Hueter  3  2/35

STAT GU4205 Linear Regression Models. 3 points.
CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: STAT GU4204 or the equivalent, and a course in linear algebra.
Theory and practice of regression analysis. Simple and multiple regression, testing, estimation, prediction, and confidence procedures, modeling, regression diagnostics and plots, polynomial regression, colinearity and confounding, model selection, geometry of least squares. Extensive use of the computer to analyze data.

Fall 2020: STAT GU4205
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
STAT 4205  001/12890  M W 6:10pm - 7:25pm  Online Only  Gabriel Young  3  28/50
STAT 4205  002/12891  M W 8:40am - 9:55am  Online Only  Ronald Neath  3  24/25
STAT 4205  003/12478  M W 11:00am - 12:15pm  Online Only  Xiaofei Shi  3  27/35
STAT 4205  004/12483  T Th 6:10pm - 7:25pm  Online Only  Haiyuan Wang  3  16/35

STAT GU4206 Statistical Computing and Introduction to Data Science. 3 points.
Prerequisites: STAT GU4204 and GU4205 or the equivalent.
Introduction to programming in the R statistical package: functions, objects, data structures, flow control, input and output, debugging, logical design, and abstraction. Writing code for numerical and graphical statistical analyses. Writing maintainable code and testing, stochastic simulations, parallelizing data analyses, and working with large data sets. Examples from data science will be used for demonstration.

Fall 2020: STAT GU4206
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
STAT 4206  001/12485  F 10:10am - 12:55pm  Online Only  Gabriel Young  3  16/46

COMS W1004 Introduction to Computer Science and Programming in Java. 3 points.
Lect: 3.
A general introduction to computer science for science and engineering students interested in majoring in computer science or engineering. Covers fundamental concepts of computer science, algorithmic problem-solving capabilities, and introductory Java programming skills. Assumes no prior programming background. Columbia University students may receive credit for only one of the following two courses: 1004 or 1005.

Fall 2020: COMS W1004
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
COMS 1004  001/11692  T Th 4:10pm - 5:25pm  Online Only  Adam Cannon  3  284/400

COMS W1005 Introduction to Computer Science and Programming in MATLAB. 3 points.
CC/GS: Partial Fulfillment of Science Requirement
A general introduction to computer science concepts, algorithmic problem-solving capabilities, and programming skills in MATLAB. Assumes no prior programming background. Columbia University students may receive credit for only one of the following two courses: W1004 or W1005.

COMS W1007 Honors Introduction to Computer Science. 3 points.
Lect: 3.
Prerequisites: AP Computer Science with a grade of 4 or 5 or similar experience.
An honors-level introduction to computer science, intended primarily for students considering a major in computer science. Computer science as a science of abstraction. Creating models for reasoning about and solving problems. The basic elements of computers and computer programs. Implementing abstractions using data structures and algorithms. Taught in Java.