Graduate Training in Formal Theory and Quantitative Methods at Princeton

Formal Theory and Quantitative Methods Faculty
Department of Politics, Princeton University

Spring 2015

This document outlines the graduate training in formal and quantitative methods available to students at Princeton. We first detail the training offered within the department and then briefly discuss alternative training available to students outside the department. The goal of the formal and quantitative methods sequences within the politics department is to produce researchers who can competently *apply* sophisticated formal and quantitative methods to important substantive questions in political science. Students who wish to become formal theorists or methodologists typically need additional training outside the sequences offered in the department, and thus they are particularly encouraged to consult with faculty members.

1 What You Should Do before Arriving at Princeton

Although our formal and quantitative methods sequences have no pre-requisite, we have observed that some of the students who have little prior exposure to the subjects struggle in our courses. We strongly recommend that students study the basics of calculus, linear algebra, and statistics before coming to Princeton. There are many online options for classes to review this material, we recommend:

- Calculus: Adrian Banner, *The Calculus Lifesaver: All the Tools You Need to Excel at Calculus*, Princeton University Press. The publisher provides video lectures from the course that uses this textbook. See `http://press.princeton.edu/video/banner/` In addition, you may also want to consult *Calculus With Analytic Geometry* by George Simmons, which has a students' solutions manual.

- Linear Algebra: Gilbert Strang, *Introduction to Linear Algebra*, 4th Edition, Wellesley-Cambridge Press. MIT Open Courseware provides video lectures, problem sets, and much more from the course that uses this textbook. See `http://ocw.mit.edu/courses/mathematics/18-06-linear-algebra-spring-2010/`

- Statistics: David Freedman, Robert Pisani, and Roger Purves, *Statistics*, W.W. Norton. In addition, it would be a good idea for you to gain some experiences of conducting data analysis.

2 Training Offered within the Department

In each semester, we offer one course in formal theory and one course in quantitative methods. Below is the list of courses that are available to students in their first and second years of the graduate school.

Year	Semester	Formal Theory	Quantitative Methods
	End of the summer	Math camp	
	Fall	POL 502	POL 571
First Year	Intersession		R camp
	Spring	POL 575	POL 572
	Before the summer		Python camp
	Fall	POL 576	POL 573
Second Year	Intersession		Advanced R camp
	Spring	POL 579	POL 574

2.1 Mathematical and Computational Foundation

Before you begin your study of the formal and/or quantitative methods, it is important to acquire the necessary mathematical foundation. Both game theory and statistics are applied subfields of mathematics, and this means that one cannot become competent users of formal and quantitative methods without learning the basic mathematical language and techniques. We offer the math camp (before the fall semester starts) and two courses in the fall semester so that students will be well prepared for a rigorous study of applied game theory and statistics that begins in the spring semester. Although we do not have any prerequisite, those who do not have a strong mathematical background should be prepared to spend a considerable amount studying the materials. In addition, modern statistical training requires students to learn basic statistical computing. We offer the R statistical programming camp where students learn basic programming skills. In addition, the advanced R statistical programming camp and Python programming camp will provide students with computing skills necessary to conduct cutting-edge data-intensive social science research.

- **Math Camp.** The math camp takes place for 10 days at the beginning of September before the fall semester starts. The participation is voluntary and the camp is taught by a graduate student. Although no formal grade is given, problem sets and exams are provided so that students can check progress on their own. The materials taught during this camp serve as the pre-requisite for POL 502 and POL 571, which will be taught during the fall semester. See http://q-aps.princeton.edu/book/math-camp-summer-2014 for details.

- **POL 502: Mathematics for Political Science.** This class is an introduction to mathematical techniques, focusing on linear algebra, real analysis, and optimization. The material covered is at the level of an undergraduate course in real analysis using a text like Lang's *Undergraduate Analysis* and linear algebra at the level of Axler's *Linear Algebra Done Right.*

- **POL 571: Quantitative Analysis I.** In this course, we cover the basic probability theory that forms the foundation of statistical theory and game theory. Towards the end of the semester, we introduce basic statistical concepts such as estimation and hypothesis testing. The materials will be covered at the level of DeGroot and Schervish (2002). *Probability and Statistics*, Addison Wesley.

- **R Statistical Programming Camp.** The R statistical programming camp takes place for several days at the end of January before the spring semester starts. The format is similar to the math camp; the participation is voluntary and the camp is taught by a graduate student. The camp is taught in order to help students learn basic programming skills necessary for applied data analysis. The camp introduces students to the statistical programming language, R, which is used in subsequent quantitative analysis courses. See http://q-aps.princeton.edu/classes/politics-statistical-programming-camp-2015 for details.

- **Advanced R Statistical Programming Camp.** The advanced R statistical programming camp builds on the R statistical programming camp that precedes POL 572 by extending the toolsets of the users to allow them to efficiently answer computationally intensive research questions. In particular, we focus on parallel execution of R code both on shared-memory systems (e.g., your laptop with multiple processors) and distributed-memory systems (e.g., the computational clusters at Princeton's Research Computing Center). Lastly, we introduce the integration of C++ into an R-based workflow and its parallelization to further speed up computation. See `http://q-aps.princeton.edu/classes/advanced-statistical-programming-camp-2015` for details.

- **Python Programming Camp.** The Python programming camp takes place for several days at the end of May before the summer. Python is a powerful programming language that allows researchers to collect and process large datasets. In this camp, researchers will learn how to use Python for web-scraping, text processing, and data manipulations. See `http://q-aps.princeton.edu/classes/web-scraping-and-text-processing-python` for details.

2.2   Formal Theory

POL 575 and POL 576 will prepare students for levels 1, 2, and 3 of the formal theory portion of the general exam.

- **POL 575: Formal Political Analysis I.** An introduction to mathematical models of political processes. Develops the analytical foundations for examining problems in collective choice. The technical development focuses on the logical structure of formal models as well as their use to develop intuition and testable hypotheses. The presentation of technical apparatus is combined with a wide range of applications. Topics include models of majority rule, direct and representative democracy, political competition under various electoral systems, international relations, and political economy. Prerequisite: POL 502.

- **POL 576: Formal Political Analysis II.** This course builds on POL 575, to further develop the analytical foundations for examining problems in collective choice. The emphasis is on the analysis of games of incomplete information and their applications in politics. Topics include include vote buying, multilateral bargaining, mechanism design, strategic information transmission, strategic voting with incomplete information, career concerns, and strategic experimentation. Readings combine textbooks and the current research literature. Prerequisite: POL 575.

- **POL 579: Topics in Formal Theory: International Relations Theory.** This course is a modern take on international relations theory focusing on the application of game theory to problems ranging from the causes of war to issues of institutional design and international political economy. Prerequisite: POL 575 and POL 551 (International Relations Seminar)

For those students who wish to learn formal theory at an introductory level may be interested in the following courses. They are undergraduate courses and cannot be counted as one of the required 14 courses. Nevertheless, these courses are appropriate for those students who wish to gain intuitive understanding of the subject in their first year before taking a more challenging graduate sequence. Permission to take these courses should be obtained from the instructor at the beginning of the semester.

- **POL 347: Mathematical Models for Politics.** This is a junior level course that teaches game theory without calculus and uses many applications from all areas of political science. This course is taught at the level of Osborne's, *Introduction to Game Theory*.

- **POL 348: Analyzing Legislatures.** Legislatures aggregate the preferences of their members into binding policy decisions. The particular way in which collective action is resolved will in general depend on the internal institutions regulating the interaction of their members. This course develops a formal apparatus to study how these different institutions alter individual and collective choices. Topics include voting rules, the spatial voting model, binary agendas, legislative bargaining, vote buying and party discipline, information and legislative organization and strategic voting with incomplete information. Readings include textbooks and some research papers. No prior knowledge of game theory is assumed.

2.3 Quantitative Methods

POL 572, POL 573, and POL 574 will prepare students for levels 1, 2, and 3 of the quantitative methods portion of the general exam, respectively.

- **POL 572: Quantitative Analysis II.** This course builds upon POL 571 and introduces students to applied regression analysis in cross-section settings. It begins with the basic principles of statistical inference, and then covers various statistical techniques including linear regression, instrumental variables, structural equation models, maximum likelihood estimation, and discrete choice models. The materials are taught at the level of Hayashi's *Econometrics*, and Freedman's *Statistical Methods*. Prerequisite: POL 502 (or permission of instructor) and POL 571

- **POL 573: Quantitative Analysis III.** This course builds upon POL 572 and introduces students to additional regression modeling and other statistical techniques frequently used in political science. The topics include generalized linear models, panel data models, survival data analysis, and statistical methods for causal inference and missing data. The materials are taught at the level of Wooldridge's *Econometric Analysis of Cross Section and Panel Data* and the second half of Gelman and Hill's *Data Analysis Using Regression and Multilevel/Hierarchical Models*. Prerequisite: POL 572

- **POL 574: Quantitative Analysis IV.** This course builds upon POL 573 and introduces students to special topics of interest. In the past, we have taught Bayesian statistics and causal inference. For Bayesian statistics, the materials are taught at the level of Gelman, Carlin, Stern and Rubin (2004) *Bayesian Data Analysis*, Chapman & Hall. Prerequisite: POL 573

Students who have never taken any statistics course are strongly encouraged to take introductory undergraduate statistics courses during their first year. These courses, while not being counted towards the required 14 courses, will serve as the solid foundation for a more challenging graduate statistics sequence. Permission to take these courses should be obtained from the instructor at the beginning of the semester.

- **POL 345: Quantitative Analysis and Politics.** This course introduces basic statistical concepts and data analysis skills up to regression. The materials are taught at the level of Freedman, Pisani, and Purves (2007) *Statistics*, Norton.

- **POL 346: Applied Quantitative Analysis.** This courses introduces various regression techniques for non-technical audience. The materials are taught at the level of the first half of Gelman and Hill (2006) *Data Analysis Using Regression and Multilevel/Hierarchical Models* Cambridge University Press.

2.4   The Political Economy Sequence

To prepare for the political economy general exam, students take two courses *both* of which require ECO 501 as a prerequisite.

- **ECO 520 Economics and Politics (cross-listed as POL 577).** Focused on analytical models of political institutions, this course is organized around canonical models and their applications. These include: voting models, menu auctions, models of reputation and cheap talk games. These models are used to explain patterns of participation in elections, institutions of congress, lobbying, payments to special interest groups and other observed phenomena. Prerequisite: ECO 501

- **POL 584 Foundations of Political Economy (cross-listed as ECO 576).** Focuses on modeling the interaction of politics and economics, with application to a variety of substantive areas. Topics include the politics of taxation and redistribution; governmental structure; and political economy of constitutional arrangements, development, and growth. Prerequisite: ECO 501.

3   Options Outside the Department

In addition to courses taught in (or cross-listed with) the Politics Department, there are additional classes offered across campus that may be of interest. Students who wish to take more advanced courses in statistics and formal theory should consult with formal and quantitative methods faculty members. In general, students are encouraged to take courses in the economics department, statistics and related courses in the Operations Research and Financial Engineering (ORFE) department, and/or machine learning courses in the computer science department.

3.1   Quantitative Methods Courses

The Center for Statistics and Machine Learning was officially launched in the summer of 2015 (see `http://sml.princeton.edu`). This is an interdisciplinary forum where faculty and students from various departments come together to share their common interests in statistics and machine learning. The official planning of the Center activities is currently under way, but there already have been a number of hires in this area including one political methodologist in the sociology department. The university has decided to invest resources in this area and we expect new hires and new courses over the next few years. For students who like to have additional training in statistics and machine learning, the following list represents example courses they could take in other departments. As the Center develops, we expect more courses to become available.

- Statistics and Machine Learning Courses in the Department of Operations Research and Financial Engineering: Analysis of Big Data (ORF 350), Statistical Theory and Methods (ORF 524), Statistical Learning and Nonparametric Estimation (ORF 525), Probability Theory (ORF 526), High Dimensional Statistics (ORF 566)

- Machine Learning Courses in the Department of Computer Science: Artificial Intelligence (COS 402), Interacting with Data (COS 427), Theoretical Machine Learning (COS 511)

- Econometrics Courses in the Department of Economics: Econometric Modeling (ECO 515), Econometric Theory I (ECO 517), Econometric Theory (ECO 518), Advanced Econometrics (ECO 519), Time Series Econometrics (ECO 513)

- Courses in the Department of Sociology: Social Network (SOC 204), Computational Social Science (SOC 596)

In addition, the following are Master's level courses on quantitative methods offered in Woodrow Wilson School.

- Quantitative analysis courses for MPA students: WWS 507b (Basic) and WWS 507c (Advanced). These courses are taught at the Woodrow Wilson School during the fall semester.

- Econometric courses for MPA students: WWS 508b (Basic) and WWS 508c (Advanced). These courses form the second half of the quantitative sequence (following up WWS 507 in the fall) offered at the Woodrow Wilson School.

- Generalized Linear Statistical Models: WWS 509. This is an alternative to WWS 508 and covers basic cross-section regression techniques.

3.2   Economics Courses

For students interested in topics that cross disciplinary lines and students doing research on political economy below is a sample of challenging courses that may be of interest.

- WWS 511D Microeconomics Analysis: This one semester course covers many key concepts from microeconomic theory, including consumer and producer theory, competitive markets, market power, information and contracts. Emphasis of the course is on developing a formal, model-based treatment of these subjects and applying them to various relevant policy issues. The course is geared to Wilson School students who did extremely well in their version of math camp (which is harder than Politics Math Camp but easier than ECO S500)–their background includes knowledge of multivariate calculus (including constrained optimization), basic probability, and some familiarity with linear algebra. Students who are intersted in taking that course should contact Karen McGuinness of the Wilson School to see whether it is possible to enroll.

- ECO S500: This is an advanced mathematics for economics course necessary for taking the PhD microeconomics course in the Economics Department. This course begins in August. Entry is regulated by a challenging "placement exam" – students who do extremely well place out of the course; others are permitted to enroll.

- ECO 501 and 502 Microeconomic Theory I and II: This is the two-term PhD sequence in microeconomic theory. Topics include consumer and producer theory, choice under uncertainty and an introduction to game theory. Prerequisite: ECO S500. Note that the Fall course ECO 501 is a prerequisite for the political economy core courses: ECO 520/POL 577 and POL 584/ECO 576.

- ECO 523 Public Finance I: This course provides a microeconomic examination of the role of government in the economy. Topics will include the theory and measurement of excess burden, optimal tax theory, the analysis of tax incidence, and an examination of the effects of taxation on behavior.

- ECO 551 International Trade: The determinants of foreign trade: (1) inter-country differences of factor endowments and technologies and (2) scale economics and imperfect competition are studied. Dynamic comparative advantage; innovation and growth; factor movements and multinational corporations; gains from trade; tariffs and quantitative restrictions on trade and their role in dealing with market failures and oligopolies; the political economy of trade policy; international negotiations on trade policy; and economic integration are studied as well. Prerequisite: ECO 501.