PhD Program in “Systems Science”
Track in “Economics, Networks and Business Analytics” (ENBA)

Course List - A.Y. 2019/20
<table>
<thead>
<tr>
<th>Course</th>
<th>Lecturer(s)</th>
<th>Hours</th>
<th>Type</th>
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<tbody>
<tr>
<td>Advanced General Equilibrium (at Sant'Anna School for Advanced Studies - Pisa)</td>
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<tr>
<td>Advanced Growth Economics (at Sant'Anna School for Advanced Studies - Pisa)</td>
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<td>Advanced Mathematics (at Sant'Anna School for Advanced Studies - Pisa)</td>
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<tr>
<td>Advanced Methods for Complex Systems I</td>
<td>Diego Garlaschelli</td>
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<td>Advanced Methods for Complex Systems II</td>
<td>Diego Garlaschelli</td>
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<td>Advanced Methods for Complex Systems III</td>
<td>Diego Garlaschelli</td>
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<tr>
<td>Advanced Topics in Econometrics</td>
<td>Francesco Serti</td>
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<tr>
<td>Advanced Topics in Network Theory: Algebraic Concepts in Network Theory</td>
<td>Guido Caldarelli</td>
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<tr>
<td>Advanced Topics in Network Theory: Brain Networks</td>
<td>Guido Caldarelli</td>
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<tr>
<td>Advanced Topics in Network Theory: Dynamical Models in Network Theory</td>
<td>Guido Caldarelli</td>
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<td>Advanced Topics in Network Theory: Research Topics in Network Theory</td>
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<td>Advanced Topics in Network Theory: Topological Concepts in Network Theory</td>
<td>Guido Caldarelli</td>
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<tr>
<td>Advanced Topics of Control Systems: Numerical Methods for Optimal Control</td>
<td>Mario Zanon</td>
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<tr>
<td>Agent-Based Macroeconomics (at Sant'Anna School for Advanced Studies - Pisa)</td>
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<td>Analytics in Economics and Management</td>
<td>Massimo Riccaboni</td>
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<td>Applications of Stochastic Processes</td>
<td>Mirco Tribastone</td>
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<td>Behavioral Economics</td>
<td>Ennio Bilancini</td>
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<td>Business Model for Emerging Markets</td>
<td>Nicola Lattanzi</td>
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<td>Cognitive Economics</td>
<td>Luca Polonio</td>
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<tr>
<td>Computer Programming and Methodology</td>
<td>Mirco Tribastone</td>
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<td>Critical Thinking (no exam)</td>
<td>Gustavo Cevolani</td>
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<td>Cybersecurity (essentials)</td>
<td>Rocco De Nicola</td>
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<td>Data Science Lab (no exam)</td>
<td>Andrea Morescaldchi</td>
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<td>Decision-Making in Economics &amp; Management</td>
<td>Massimo Riccaboni</td>
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<td>Dynamic Macroeconomics (at Sant'Anna School for Advanced Studies - Pisa)</td>
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<td>Econometrics (at Sant'Anna School for Advanced Studies - Pisa)</td>
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<td>Econometrics 1</td>
<td>Paolo Zacchia</td>
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<td>Econometrics 2</td>
<td>Armando Rungi</td>
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<td>Economic Growth (at Sant'Anna School for Advanced Studies - Pisa)</td>
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<td>Economics of Innovation (at Sant'Anna School for Advanced Studies - Pisa)</td>
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<td>Evolutionary Foundations of Industrial Dynamics (at Sant'Anna School for Advanced Studies - Pisa)</td>
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<td>Evolutionary Game Theory</td>
<td>Ennio Bilancini</td>
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<td>Financial Economics (at Sant'Anna School for Advanced Studies - Pisa)</td>
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<td>Firms, Business Analytics and Managerial Behavior</td>
<td>Nicola Lattanzi</td>
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<td>Foundations of Probability and Statistical Inference</td>
<td>Irene Crimaldi</td>
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<tr>
<td>Funding and Management of Research and Intellectual Property (no exam)</td>
<td>Marco Paggi</td>
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<td>Game Theory</td>
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<td>Global Law</td>
<td>Andrea Averardi</td>
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<td>History of Economic Thought (at Sant'Anna School for Advanced Studies - Pisa)</td>
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<td>Identification, Analysis and Control of Dynamical Systems</td>
<td>Alberto Bemporad</td>
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<td>Industrial Dynamics (at Sant'Anna School for Advanced Studies - Pisa)</td>
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<td>Industrial Organization</td>
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<td>Industrial Organization and Market Failure (at Sant'Anna School for Advanced Studies - Pisa)</td>
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<td>Introduction to Agent-Based Economics (at Sant'Anna School for Advanced Studies - Pisa)</td>
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<td>Introduction to Economic History (at Sant'Anna School for Advanced Studies - Pisa)</td>
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<td>Introduction to Macroeconomics (at Sant'Anna School for Advanced Studies)</td>
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<td>Introduction to Network Theory</td>
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<td>Machine Learning</td>
<td>Giorgio Gnecco</td>
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<td>Macroeconomics (at Sant'Anna School for Advanced Studies - Pisa)</td>
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<td>Markov Processes (at Sant'Anna School for Advanced Studies - Pisa)</td>
<td>Irene Crimaldi</td>
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<td>Matrix Algebra</td>
<td>Giorgio Gnecco</td>
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<td>Microeconometrics (at Sant'Anna School for Advanced Studies - Pisa)</td>
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<td>Microeconomics</td>
<td>Kenan Huremovic; Andrea Canidio</td>
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<td>Models of Causality and Explanation in Economics (at Sant'Anna School for Advanced Studies - Pisa)</td>
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<td>Neurobiology of Emotion and Behavior</td>
<td>Pietro Pietrini</td>
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<td>Non Parametric Statistics (at Sant'Anna School for Advanced Studies - Pisa)</td>
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<td>Numerical Methods for the Solution of Partial Differential Equations</td>
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<td>Numerical Optimization</td>
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<td>Optimal Control</td>
<td>Giorgio Gnecco</td>
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<td>Philosophy of Science (no exam)</td>
<td>Gustavo Cevolani</td>
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<td>Political Economy</td>
<td>Alessandro Belmonte</td>
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<td>Socio-Economic Networks</td>
<td>Massimo Riccaboni</td>
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<td>Static and Dynamic Optimization (at Sant'Anna School for Advanced Studies - Pisa)</td>
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<td>Statistical Methods for Large Complex Data (at Sant'Anna School for Advanced Studies - Pisa)</td>
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<td>Stochastic Processes and Stochastic Calculus</td>
<td>Irene Crimaldi</td>
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<td>Strategies and Business Behavior</td>
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<td>Theories of the Firm (at Sant'Anna School for Advanced Studies - Pisa)</td>
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<td>Time Series (at Sant'Anna School for Advanced Studies - Pisa)</td>
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<td>Topics in Macro (at Sant'Anna School for Advanced Studies - Pisa)</td>
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Advanced General Equilibrium
(Sant'Anna School for Advanced Studies - Pisa)
Details available [here](#).

Advanced Growth Economics (at Sant'Anna School for Advanced Studies - Pisa)
Details available [here](#).

Advanced Mathematics (at Sant'Anna School for Advanced Studies - Pisa)
30 hours
Details available [here](#).
Advanced Methods for Complex Systems I
Diego Garlaschelli
20 hours

Learning Outcomes:
Students will learn how to: identify the properties of real-world complex systems that defeat traditional tools of analysis across different disciplines and research fields; design advanced methods to empirically characterise, mathematically model and computationally simulate those properties.

Abstract:
This interdisciplinary course aims at introducing rigorous tools from statistical physics, information theory and probability theory for investigating real-world complex systems arising in different fields of research. First, some key aspects of complexity encountered in physical, biological, social, economic and technological systems will be reviewed. Then, emphasis will be put on the construction of theoretical models based on the concept of constrained randomness, i.e. the maximisation of the entropy subject to suitable constraints. This will lead to the introduction of maximum-entropy models that serve as mathematical benchmarks for the properties of highly heterogeneous systems. Special cases of interest for this first part of the course include statistical ensembles of time series and correlation matrices with given properties. Applications to pattern detection in econophysics and neuroscience will be discussed. Full mathematical derivations of the models, as well as methods of statistical inference and model selection for data analysis will be provided.

Lecture Contents:
- Introduction
- From Complexity to Thermodynamics
- From Thermodynamics to Statistical Physics
- Entropy in Probability Theory
- Entropy in Information Theory
- Empirical patterns in univariate time series
- Empirical patterns in multivariate time series
- Community detection for correlation matrices

Teaching Method: Combination of frontal lectures, blackboard discussions and students' presentations.

Bibliography: References to relevant research papers are gradually provided during the lectures. Lecture slides and other course materials are regularly distributed to the students.

Final Exam:
Consists of students’ presentations of research papers, around which the professor organises a critical discussion with the rest of the class, towards the end of the course. No additional time slot for the exam is therefore scheduled.

Prerequisites: Solid mathematical background, scientific curiosity, logical rigor, interest in
multidisciplinarity, passion for theory.
Advanced Methods for Complex Systems II  
Diego Garlaschelli  
20 hours

Learning Outcomes:  
Students will learn how to: identify the properties of real-world complex systems that defeat traditional tools of analysis across different disciplines and research fields; design advanced methods to empirically characterise, mathematically model and computationally simulate those properties.

Abstract:  
The second part of the course “Advanced Methods for Complex Systems” focuses on advanced practical applications of the concepts introduced in the first part. In particular, emphasis will be put on the successful areas of pattern detection and network modelling. Network pattern detection is the identification of robust empirical patterns (like scale-invariance, clustering, assortativity, reciprocity, motifs, etc.) that are widespread across real-world networks and that deviate systematically from some null hypothesis formalised in terms of a suitable random graph model. The models introduced in part 1 will then be used here for pattern detection purposes. Similarly, they will be used for modelling the properties of real networks in terms of explanatory factors. The course will include a combination of recent and ongoing research in the NETWORKS unit at IMT Lucca, thereby offering directions for possible PhD projects in this area.

Lecture Contents:  
- Complex networks: robust empirical properties  
- Maximum-entropy network ensembles  
- Networks with given degree sequence  
- Maximum likelihood parameter estimation in network ensembles  
- Pattern detection in networks  
- Reciprocity and the Reciprocal Configuration Model  
- The International Trade Network (econometric vs network modelling)

Teaching Method: Combination of frontal lectures, blackboard discussions and students' presentations.

Bibliography:  
References to relevant research papers are gradually provided during the lectures. Lecture slides and other course materials are regularly distributed to the students.

Final Exam:  
The final consists of students’ presentations of research papers, around which the professor organises a critical discussion with the rest of the class, towards the end of the course. No additional time slot for the exam is therefore scheduled.

Prerequisites: Solid mathematical background, scientific curiosity, logical rigor, interest in multidisciplinarity, passion for theory. Successful completion of the course “Advanced Methods for
Complex Systems 1".
Advanced Methods for Complex Systems III  
Diego Garlaschelli  
20 hours

Learning Outcomes:  
Students will learn how to: identify the properties of real-world complex systems that defeat traditional tools of analysis across different disciplines and research fields; design advanced methods to empirically characterise, mathematically model and computationally simulate those properties.

Abstract:  
The course focuses on the problem of network reconstruction from partial topological information and on the different physical and mathematical properties found when the input information is treated as a “soft” or a “hard” constraint.  
On the side of applications, emphasis will be put on the reconstruction of financial and interbank networks from node-specific properties, with the purpose of improving stress tests and systemic risk estimates in real markets and offering better tools to policy makers. The methods recently found by central banks to be the best-performing reconstruction techniques will be reviewed in detail.  
On the side of theory, the surprising breakdown of the equivalence of statistical ensembles constructed from soft and hard constraints will be discussed. We will show how this breakdown affects all models of complex systems encountered throughout the three parts of the course. Finally, we discuss deep implications for data compression, information theory and combinatorial enumeration.

Lecture Contents:  
- From binary networks to weighted networks: the Weighted Random Graph  
- The Weighted Configuration Model  
- The Enhanced Configuration Model  
- The Enhanced Gravity Model  
- Network reconstruction in various settings  
- Adaptive Networks  
- Breaking of ensemble equivalence  
- Relative entropy between ensembles  
- Weak and strong ensemble nonequivalence  
- Applications to combinatorial enumeration and data compression

Teaching Method: Combination of frontal lectures, blackboard discussions and students' presentations.

Bibliography:  
References to relevant research papers are gradually provided during the lectures. Lecture slides and other course materials are regularly distributed to the students.

Final Exam:  
The final consists of students’ presentations of research papers, around which the professor organises a critical discussion with the rest of the class, towards the end of the course. No additional time slot for the
exam is therefore scheduled.

**Prerequisites:**
Solid mathematical background, scientific curiosity, logical rigor, interest in multidisciplinarity, unlimited passion for theory. Successful completion of the courses “Advanced Methods for Complex Systems 1” and “Advanced Methods for Complex Systems 2”
Advanced Topics in Econometrics
Francesco Serti
20 Hours

Learning Outcomes:
The aim of the module is to bridge the step from a technical econometrics course to doing applied research. The emphasis will be on the application of the methods, rather than the technical details about them. As such, the goal is to provide students with enough knowledge to understand when these techniques are useful and how to implement each method in their empirical research.

Abstract:
This module covers some of the most important methodological issues arising in any field of applied economics when the main scope of the analysis is to estimate causal effects. A variety of methods will be illustrated using theory and papers drawn from the recent applied literature.

Lecture Contents:
1 Causality and Randomized Experiments
   a) Structural and Treatment Effects approaches
   b) Basic questions in empirical research
   c) Rubin Causal model
   d) Social Experiments
   e) Application I: Krueger (1999) on class size and educational test scores
   f) Application II: Atkin et al. (2017) on exporting and firm performance: evidence from a randomized experiment
2 Regression and Causality
   a) Properties of the Conditional Expectation Function
   b) Bad controls
   c) Sources of bias
   d) Conditional Independence Assumption
3 Instrumental variables
   a) Basics/recap
   b) IV and causality
   c) IV with heterogeneous treatment effects – LATE
   d) Weak instruments
   e) The bias of 2SLS
   g) Application IV: Nunn (2009) on slave trades and economic performances
4 Matching
   a) Covariate Matching
   b) Propensity Score Matching
   c) Inverse Probability Weighting
   d) Entropy balancing
   e) Regression adjustment
f) Application V: Angrist (1998) on the labor market impact of voluntary military service (matching meets regression)

5 Differences-in-Differences
   a) Basics
   b) Regression Differences-in-Differences
   c) Robustness checks and picking a good control group
   Application VII: Card & Krueger (1994) on minimum wage and unemployment

6 Regression Discontinuity Design
   a) Sharp RD
   b) Fuzzy RD
   c) Running RD Models
   e) Application IX: Angrist & Lavy (1999) on scholastic achievement

7 The Synthetic Control Method
   a) Basics
   b) Multiple treated units
   c) Robustness checks and inference
   d) Application X: Abadie et al. (2010) on the Effect of California’s Tobacco Control Program

**Teaching Method:** The emphasis will be on the application of the methods, rather than the technical details about them. After a review of the theory behind each empirical method, we will focus on their practical implementation and on some examples from the applied economic literature.

**Bibliography:**

**Final Exam:**
The assessment is based on the production of a short empirical essay. To do the project students will need to provide a clear research question and a feasible empirical strategy; collect relevant data; implement an appropriate method chosen among one of those explored in the module; draw conclusions and write up the results in a standard academic style in less than 3,000 words.

**Prerequisites:** Econometrics 1; Econometrics 2
Advanced Topics in Network Theory: Algebraic Concepts in Network Theory
Guido Caldarelli
10 Hours

Learning Outcomes:
Manipulation of adjacency matrices and algorithms connected

Abstract:
we shall provide the definitions of the algebraic concepts lying at the core of network theory and shall introduce the principles of network analysis with Python. This module is propaedeutic for modules 3, 4, 5.

Lecture Contents:
Binary, undirected networks: basic definitions; spectral properties; functions of the adjacency matrix. Other network representations (directed, weighted, bipartite, multiplex networks) and generalization of the results above. Other representations of network data (5h)
Python: Jupiter notebook; variables, lists, dictionaries; loops (for, while); functions; files management; errors (2h)
NumPy: arrays and functions; spectral properties; other representations for large datasets (3h)

Teaching Method:
Slides and Lab

Bibliography:
- Easley, Kleinberg "Networks Crowds and Markets" CUP (2010)
- http://barabasilab.neu.edu/networksciencebook/
- G. Caldarelli A. Chessa Data Science and Complex Networks OUP (made available to students)

Final Exam:
the candidate will work in the classroom and we shall assign a “pass” or “retake” vote at the end of the course.

Prerequisites: Introduction Course
Advanced Topics in Network Theory: Brain Networks
Guido Caldarelli
10 Hours

Learning Outcomes:
to be able to know the functioning of the various measuring instruments and to be able to correlate and model different measures on brain activity. We also want to teach brain structure and areas of interests

Abstract:
we shall provide the tools to measure and analyze the different kinds of networks that can be defined when studying the human brain (e.g. the functional and the structural one).

Lecture Contents:
Physics of the measuring instruments, structure of the Brain, connectome, networks from time series

Teaching Method:
slides and working in groups on pc

Bibliography:
● G. Caldarelli Scale-Free Networks OUP (2007) (made available to students).
● Easley, Kleinberg "Networks Crowds and Markets” CUP (2010)
● http://barabasilab.neu.edu/networksciencebook/
● Other texts will be suggested in the various lectures (basic biblio in this list)

Final Exam:
the candidate will work in the classroom and we shall assign a "pass" or "retake" vote at the end of the course.

Prerequisites:
Introduction to Complex Networks
Advanced Topics in Network Theory: Dynamical Models in Network Theory
Guido Caldarelli
10 Hours

Learning Outcomes:
Being able to generate synthetic networks through computer coding

Abstract:
we shall review the most popular growth models for networks, the details of the most studied dynamical processes on networks and their implementation in Python.

Lecture Contents:
Growth models: the Barabasi-Albert original model; further properties of the Barabasi-Albert model; the Bianconi-Barabasi model; the Medo-Cimini-Gualdi model (4h)
Dynamics "of" and "on" networks: small-world model; percolation; epidemics on networks (4h)
Exercises in Python + NetworkX (2h)

Teaching Method:
slides and working groups

Bibliography:
- Easley, Kleinberg "Networks Crowds and Markets" CUP (2010)
- http://barabasilab.neu.edu/networksciencebook/
- Other texts will be suggested in the various lectures (basic biblio in this list)

Final Exam:
The candidate will work in the classroom and we shall assign a “pass” or “retake” vote at the end of the course.

Prerequisites:
Introduction and Algebraic properties.
Advanced Topics in Network Theory: Research Topics in Network Theory
Guido Caldarelli
10 hours

Learning Outcomes:
To be able to select stat-of-the-art problems in the area of complex networks

Abstract:
we shall review the latest developments in research concerning the field of network theory. This module requires module 2. The course “Advanced Methods for Complex Systems I” is suggested as a prerequisite.

Lecture Contents:
The Exponential Random Graph Model: constrained entropy maximization; parameter estimation; computing expectations and errors; a quick look at perturbation theory for networks (2h)
Hypothesis testing on networks: projecting and filtering bipartite networks; early-warning signals detection; community detection techniques for correlation matrices (asset graph, MSF, dendrogram-cutting, the Masuda approach, random matrix theory-based techniques) (3h)
Network reconstruction; applications to the World Trade Web; comparison between network models and econometric models; applications to financial networks; link prediction (3h)

Teaching Method:
slides and working on pc

Bibliography:
• G. Caldarelli Scale-Free Networks OUP (2007) (made available to students).
• Easley, Kleinberg "Networks Crowds and Markets" CUP (2010)
• http://barabasilab.neu.edu/networksciencebook/
• Other texts will be suggested in the various lectures (basic biblio in this list)

Final Exam:
The candidate will work in the classroom and we shall assign a “pass” or “retake” vote at the end of the course.

Prerequisites:
Introduction to Network Theory.
Advanced Topics in Network Theory: Topological Concepts in Network Theory
Guido Caldarelli
10 Hours

Learning Outcomes:
To be able to work on graphs as for example to be able to detect centrality and communities structures

Abstract:
We shall introduce the definitions of the main topological quantities of interest in network theory and their implementation in Python.

Lecture Contents:
Centrality metrics: degree; closeness; betweenness; eigenvector; Katz; hub/authority; PageRank (2h)
Exercises in Python + NetworkX (2h)
Mesoscale structures detection: Girvan-Newman algorithm and modularity; spectral methods; Louvain;
the limitations of modularity; surprise; block-model fitting; community detection for bipartite networks;
core-periphery structure; bow-tie structure (6h)

Teaching Method:
Slides and lab

Bibliography:
• G. Caldarelli Scale-Free Networks OUP (2007) (made available to students).
• Easley, Kleinberg “Networks Crowds and Markets” CUP (2010)
• http://barabasilab.neu.edu/networksciencebook/
• G. Caldarelli A. Chessa Data Science and Complex Networks OUP (made available to students)

Final Exam:
The candidate will work in the classroom and we shall assign a “pass” or “retake” vote at the end of the course.

Prerequisites:
This module requires module 2 (Algebraic properties) and Introduction to Networks.
Learning Outcomes:
The students will learn how to properly formulate and solve an optimal control problem using state-of-the-art techniques.

Abstract:
Many control and estimation tasks seek at minimizing a given cost while respecting a set of constraints, which belongs to the class of problems denoted as Optimal Control (OC). The most practical approach to solve OC problems is via direct methods, which consists in discretizing the problem to obtain a Nonlinear Program (NLP) which is then solved using one of the many available approaches. The course will be introduced by an overview of the available classes of algorithms for OC and place direct methods in this context. The core of the course is structured around the following two main parts.

NLP solvers:
This part of the course first establishes a sound theoretical background on the characterization of local minima (maxima) by introducing geometric optimality concepts and relating them to the first- and second-order conditions for optimality, i.e. the Karush-Kuhn-Tucker conditions, constraint qualifications and curvature conditions. Second, the theoretical concepts will be used to analyze the most successful algorithms for derivative-based nonconvex optimization, i.e. Sequential Quadratic Programming and Interior Point Methods, both based on Newton's method. Since there does not exist a plug-and-play NLP solver, attention will be devoted to giving the students a solid understanding of the mechanisms underlying the algorithms so as to endow them with the ability to formulate the problem appropriately and choose the adequate algorithm for each situation.

Discretization techniques:
This second part of the course covers the most successful discretization approaches, i.e. single-shooting, multiple-shooting and collocation. All mentioned approaches rely on the simulation of dynamical systems, for which a plethora of algorithms have been developed. The students will be explained the features of the different classes of algorithms, with particular attention on the numerical efficiency, simulation accuracy and sensitivity computation. Finally, the structure underlying the NLP obtained via direct methods for OC will be analyzed in order to understand the immense benefits derived from developing dedicated structure-exploiting OC solvers.

Advanced Topics:
The course will be concluded by two lectures on parametric sensitivities, path-following methods and Nonlinear Model Predictive Control (NMPC) with considerations on stability, tuning and real-time solvers.

Lecture Contents:
The following lectures are divided by topic in the order in which they will be presented. Some lecture
requires more than 2 hours and some other requires less. Altogether, the 9 lectures require 20 hours of teaching, which will be supported by 10 hours of supervision for the solution of the assignments.

1. Introduction to optimal control
2. Nonlinear Programming: optimality characterization
3. Newton’s method and algorithms for nonconvex optimization
4. Shooting methods
5. Numerical integration with sensitivities
6. Collocation methods
7. Structure of discretized optimal control problems
8. Parametric sensitivity and path-following
9. Nonlinear Model Predictive Control

Teaching Method:
Lectures and exercise sessions

Bibliography:
L. Biegler. Nonlinear Programming, MOS-SIAM Series on Optimization 2010
J. C. Butcher Numerical Methods for Ordinary Differential Equations, Wiley 2016

Final Exam:
Solution of all the assignments

Prerequisites:
Basic knowledge in dynamical systems and linear algebra. Some knowledge on numerical optimization and simulation can be helpful but is not required.
Agent-Based Macroeconomics
(Sant'Anna School for Advanced Studies - Pisa)
Details available here.
Learning Outcomes:
The aim of this course is to teach students how to produce a research paper in economics and management using hands-on empirical tools for different data structures.

Abstract:
The aim of this course is to teach students how to produce a research paper in economics and management using hands-on empirical tools for different data structures. We will bridge the gap between applications of methods in published papers and practical lessons for producing your own research. After introductions to up-to-date illustrative contributions to literature, students will be asked to perform their own analyses and comment results after applications to microdata provided during the course.

How productive is a firm, an industry or a country? Why? Where is it more profitable to locate an economic activity? Who buys what products? How long can we expect a company to outlive its competitors? What is the relationship between economic welfare and size of a city? How do economic agents interact socially in a geographic space or in a workplace? The objective is to develop a critical understanding of the iterative research process leading from real economic data to the choice of the best tools available from the analyst kit. Students are expected to be familiar with microeconomics and econometrics from the first-year sequence.

Lecture Contents:
Class 1: Introduction
Class 2: Challenges of Big Data Analysis
Class 3: New Tricks for Econometrics and Artificial Intelligence
Class 4: Statistical Learning with Sparsity: The Lasso and Generalizations
Class 5: Classification and Regression Trees
Class 6: Bayesian statistical learning
Class 7: Using Big Data for Measurement and Research
Class 8: Matrix Completion and Networks
Class 9: Big Data, Big Cities, Global Studies
Class 10: Mining Text

Teaching Method:
Lecture-cum-Demonstration

Bibliography:

**Final Exam:**

Final scores will be based 50% on individual presentations of a selected supplemental reading and 50% on an individual homework.

**Prerequisites:**

Microeconomics, Econometrics I & II
Applications of Stochastic Processes
Mirco Tribastone
20 Hours

Learning Outcomes:
To provide students with basic tools for the modeling and analysis of systems using stochastic processes.

Abstract:
This course offers an introduction to stochastic processes as a practical modelling tool for the quantitative analysis of systems. It covers the fundamentals of Markov chains, and presents algorithms and state-of-the-art software applications and libraries for their numerical solution and simulation. The class of Markov Population Processes is presented, with its most notable applications to as diverse disciplines as chemistry, ecology, systems biology, health care, computer networking, and electrical engineering. Finally, the course will examine the computational issues arising from the modelling of large-scale systems, reviewing effective approximation methods based ordinary differential equation (fluid) limits, moment-closure techniques, and hybrid models.

Lecture Contents:
Introductions to discrete- and continuous-Markov chains; examples (Page Rank, reaction networks, queuing networks); Markov population processes; stochastic simulation algorithms; fluid approximations of Markov population processes; software tools for analysing Markov chains.

Teaching Method:
Blackboard and slides.

Bibliography:
Bibliographic material will consist of research articles distributed throughout the course.

Final Exam:
Student may choose between the presentation of a research paper or the development of project

Prerequisites:
None
Behavioral Economics
Ennio Bilancini
20 Hours

Learning Outcomes:
The goal of the course is to provide an all-purpose introduction to behavioral economics as well as to offer hooks and suggestions for cutting-edge research projects concerning bounded rationality and prosocial behavior.

Abstract:
The course is a self-contained presentation and discussion of state-of-the-art research in behavioral economics, an area merging economics and psychology for the purpose of modelling and predicting human decision-making and behavior.

Lecture Contents:
1. What is Behavioral Economics? An economist’s take on surprising human behaviors, with a reference to why psychologists and neuroscientists are hardly surprised
2. Rationality with cognitive bounds: Searching for predictable mistakes
3. Beyond homo economicus: Searching for predictable other-regarding preferences
4. A case study in behavioral game theory: Cognitive foundations of human prosociality
5. A discussion on methods: Experiments by economists in the lab and in the field, with a reference to how psychologists and neuroscientists would disagree

Teaching Method:
Frontal lectures

Bibliography:

Final Exam:
A 10-page essay applying behavioral economics to a phenomenon decided by the student

Prerequisites:
The course is self-contained, but basic knowledge of microeconomics and choice theory are welcome.
Learning Outcomes:
Students will learn how to observe and evaluate business behavior, as well as how to locate sources of potential competitive advantage. They will also learn the base to identify organizational barriers and corporate behaviors that sustain or challenge manager decisions and execution of strategies.

Abstract:
The course is based on key business concepts that will support students develop the expertise required to understand and evaluate business behaviors, firms’ strategies and financial results. The course is composed of three modules: "Firms, business analytics and managerial behavior", "Business Behavior and Behavioral Strategy", "Business model for emerging markets".
The course will describe the decision-making in competitive markets as well as in emerging markets at the business unit level, in which many key strategic choices and actions are formulated and undertaken. The essential “tool-kit” that combines a broad understanding of strategies, businesses and market dynamics and the new challenges of businesses in today’s world.

Lecture Contents:
Business Model for Emerging Markets
1. What makes the economy emerging and the market new?
2. Fintech challenge: centralized economy versus decentralized economy? Decentralized organizations and business models? DAO, DAC and others
3. Digital Economy: effects and implications on business modeling, business plan and business reporting
4. Family business and Italian SMSB: “Made in a recognizable place”
5. A business model for a global value chain approach in a Digital Economy. The smile curve: where value is added along supply chains
6. The new Silk Road - Belt and Road: Avoiding Errors, Discovering Opportunities
7. Creation of needs, emerging behaviors and business dynamics: the interaction of neuroscience and technology for business and strategy (joint E. Ricciardi)
8. Zombie Economy and Zombie Firms: The Emerging Phenomena
9. Network approach for Business modeling and decision making process
10. The role and function of studies in management science and business strategy. The emerging scenario.

Teaching Method:
Lectures, discussions, business cases, presentations.

Bibliography:
Suggested readings will be provided for each topic.

Final Exam: Critical paper presentations in at least four groups.
**Prerequisites:**
Basic knowledge of business economics.
Cognitive Economics  
Luca Polonio  
20 Hours

**Learning Outcomes:**
At the end of the course, the student should have a clear understanding of different methods in the field of cognitive economics. The student should be able to design an experiment to investigate simple economic decision making processes. The student should be able to recognize the weaknesses and strengths of published articles, starting from the research question, through the method used, to the reporting of the project’s outcome.

**Abstract:**
The goal of the course is to provide an introduction to cognitive economics and a balanced view of the possibilities of the process tracing approach, which is the investigation of the processes underlying choice behavior. In addition, this course aims to provide an overview of different models of choice, such as drift diffusion and rational inattention models. Finally, the course aims to provide a practical understanding of different methods from psychophysics, including the analysis of reaction time, mouse-lab and eye-tracking for students interested in designing their own psychophysics experiments.

**Lecture Contents:**
1) What is Cognitive Economics;  
2) Methods from psychophysics to the investigation of decision making (Analysis of reaction time, mouse-lab and eye-tracking)  
3) Drift diffusion model;  
4) Rational inattention;  
5) The Role of Cognitive Abilities in Decision Making;  
6) Bounded Rationality and Social Preferences;  
7) The Role of Emotion in Decision Making

**Teaching Method:** Lectures/oral presentations

**Bibliography:**

**Final Exam:**
Writing of a research project proposal; Critical analysis essay on an article

**Prerequisites:**
While a general understanding of behavioral economics and game theory is welcome, no prerequisite is strictly necessary.
Learning Outcomes:
This course aims to provide students with basic principles and methodologies of computer programming using Python. It is aimed particularly to students without a computer science background. The main objective is to develop the necessary skills to effectively read, write, and maintain computer programs. It provides background for facilitating the understanding of advanced programming classes as well as the proficiency with domain-specific software libraries and tools.

Abstract:
The course will cover the basic principles of programming, starting from the interaction between programs and the environment (memory, input/output) in which they execute. It will discuss: fundamental programming constructs (conditional statements, loops); how to effectively structure code using functions; recursion; object-oriented programming; basics of functional programming; memory management for programs (garbage collection). The Python programming language will be used to demonstrate these concepts and to develop simple illustrative programs that will be presented throughout the course.

Lecture Contents:
Introduction to computer architectures; programming; variables; data structures and Python sequences; memory management; conditional statements; for and while loops; functions; basics of object-oriented programming; basics of functional programming.

Teaching Method:
Blackboard; slides; programming tutorials

Bibliography:
M. Lutz. Learning Python, O'Reilly.

Final Exam:
Group project

Prerequisites:
None.
Learning Outcomes:
The course aims at improving the students’ skills in understanding, presenting and evaluating problem statements and arguments. After following the course, students will be able to rigorously distinguish between "strong" and "weak" arguments; they can formulate and analyze theses and hypotheses and evaluate the impact that evidence and information has on them; and they can better draw logical and effective conclusions from both hypotheses or evidence.

Abstract:
Constructing and evaluating arguments is fundamental in all branches of science, as well as in everyday life. The course provides the basic tools to recognize and analyze correct forms of inference and reasoning, detect the unsound or fallacious ones, and assess the strength of various kinds of argument. The toolbox includes elementary deductive logic, naïve set theory, patterns of inductive and abductive inference, and elements of statistical and probabilistic reasoning. By engaging in real-world exercises of correct and incorrect reasoning, students will familiarize with basic epistemological notions (truth vs. certainty, knowledge vs. belief, theory vs. evidence, etc.), with the analysis of relevant informal concepts (like truth, falsity, lies, misinformation, disinformation, post-truth, fake news, rumors, etc.) and with common reasoning pitfalls, heuristics and biases as investigated in cognitive psychology and behavioral economics.

Lecture Contents:
Lecture 1. Presentation of the course. Discussion and choice of specific topics. Arguments and statements.
Lecture 2. Evaluating statements: Truth, certainty, informativeness, truthlikeness, etc. Relativism and post-truth.
Lecture 8. Recap, verification and general discussion.

Teaching Method:
Mixture of lectures and discussion seminar.

Bibliography:
We won’t have a textbook or a proper reading list. Relevant readings will be shared on Google Drive. The following are useful general texts on the main topics of the course (all of them are owned by the IMT
Library).

**Final Exam:**
Active contribution from the participants is a prerequisite for passing the course.

**Prerequisites:**
None
Learning Outcomes:
Methods for navigating securely and for defending assets and privacy.

Abstract:
The course is structured in two modules. The first module is introductory to cybersecurity in general and teaches methods for navigating securely and for defending assets and privacy. It can be beneficial for any student and does not assume any prior technical knowledge. The second module covers some advanced topics in cybersecurity such as security protocols, usage control, vulnerability analysis and web and mobile security.

Lecture Contents:

Teaching Method:
Blackboard; slides.

Bibliography:
Handouts with the slides, introductory books, research papers.

Final Exam:
No exam.

Prerequisites:
No prerequisite.
Data Science Lab
Andrea Morescalchi
40 Hours

Learning Outcomes:
(1) Knowledge of the most relevant functionalities in Stata to carry out data management and exploratory analysis.
(2) To achieve autonomy in application of econometric techniques to real data.

Abstract:
The aim of this course is to provide students with fundamentals of Stata language to conduct data management and exploratory analysis, and implement a variety of econometric techniques to address typical research questions in Economics.

Lecture Contents:
Lectures will cover the following topics:
– Introduction to Stata, descriptive statistics, fundamentals of inference
– OLS regression
– Non-linear models (binary, multinomial, count outcomes)
– Panel methods (pooled OLS, Fixed Effects, Random Effects, First Difference, Generalized Least Squares)
– Impact Evaluation (Randomized experiments, Matching, Difference-in-differences, Instrumental Variables, Regression Discontinuity Design)

Teaching Method:
Computer-based

Bibliography:
Cameron, A. C., P. K. Trivedi (2009) Microeconometrics Using Stata. Stata Press

Final Exam:
Not required

Prerequisites:
Basic Statistics.
Learning Outcomes:
The main goals of the course are: (1) to take marketing theories and methodologies out into the world, applying them to interesting questions of individual behavior and societal outcomes; (2) to develop a basic understanding of human psychology and social dynamics as they apply to marketing contexts; (3) to become familiar with the major theory and research methods for analyzing consumer behavior; (4) to develop market analytics insight into consumer actions.

Abstract:
This class is structured into two parts: 1) general knowledge relating to basic conceptual notions of marketing and consumer behavior; and 2) heritage marketing. Most of the time will be devoted to close reading of textbooks and research papers, including a discussion of the relative merits of particular methodologies. Students will participate actively in class discussion, engage with cutting-edge research, evaluate empirical data, and write an analytical paper. The course aims at enabling students to develop and enhance their own skills and research interests.

Lecture Contents:
1. Course overview, consumer behavior; Chapters 1-4, Principles of Marketing
2. Marketing to create value, theory and practice; Chapters 5-9, Principles of Marketing
3. The Marketing Plan; Chapters 14-16, Principles of Marketing
4. Heritage marketing
5. Behavioral economics insights, guidelines for final paper

Teaching Method:
Lecturing

Bibliography:
The main textbook for this course is entitled “Principles of Marketing” and is freely available online https://open.lib.umn.edu/principlesmarketing/.


Additional readings will be provided by the instructor based on students’ research interests (see Google Drive)

Final Exam:
50 % Participation. Attendance is required and will be recorded. The teaching format is interactive, i.e. active discussion is expected between students and instructor and will be part of the student evaluation. Abstract concepts will be understood through real life examples and observations.
50 % Final Paper. You will select a topic related to marketing and consumer decision making and write a paper.

**Prerequisites:**
none
Dynamic Macroeconomics
(Sant'Anna School for Advanced Studies - Pisa)
Details available here.

Econometrics
(Sant'Anna School for Advanced Studies - Pisa)
Details available here.
Learning Outcomes:
The objective of the course is to provide a firm understanding of the core theory of Econometrics at the graduate level.

Abstract:
This course provides a general introduction to modern econometrics. Following a review of fundamental concepts of probability theory, the course illustrates the fundamental linear and non-linear models at the core of econometrics, under the unifying framework of Maximum Estimation. Emphasis is placed upon the concepts of structure, identification, causality; their mutual relationships; as well as their connection to the actual econometric practice.

Lecture Contents:
1) Probability Review
2) Asymptotics Review
3) Structure, Identification and Causality
4) The Linear Regression Model
5) Least Squares Estimation
6) Endogeneity and Instrumental Variables
7) Simultaneous Equations Model
8) Introduction to Maximum Estimation
9) Maximum Likelihood Estimation
10) Generalized Method of Moments

Teaching Method:
Traditional frontal instruction accompanied by optional practice hours

Bibliography:
A. Colin Cameron and Pravin K. Trivedi (2005), Microeconometrics: Methods and Applications, Cambridge University Press
William H. Greene (2012), Econometric Analysis, Pearson
Other notes and scientific articles will be distributed in class

Final Exam:
The assessment is based upon a final written exam (for about 70% of the final grade) as well as on two extensive problem sets (for about the remaining 30%).

Prerequisites:
Multivariate calculus, linear algebra, graduate-level probability and statistical inference.
Econometrics II
Armando Rungi
20 Hours

Learning Outcomes:
The objective is to develop a critical understanding of the iterative research process leading from real economic issues to the choice of the best tools available from the analyst kit.

Abstract:
This course covers the most important topics of modern microeconometrics. A variety of methods are illustrated with a hands-on-tool approach combining theory and practice. The objective is to develop a critical understanding of the iterative research process leading from real economic issues to the choice of the best tools available from the analyst kit. The assessment is based on the production of a short empirical project (50%), a written exam (30%) and the presentation/replication of a published scientific article (20%).

Lecture Contents:
1) Introduction to Microeconometrics
   i) Heterogeneity and Microdata
   ii) The Potential Outcome Model
   iii) Exogeneity and Identification
   iv) Parametric, Semiparametric and Non-parametric Models
   v) The Local Polynomial Regression Model
   vi) The Kernel Density Estimation

2) Survey Design, Sampling and Variance
   i) Survey design and Sampling Techniques
   ii) The Heckman Correction
   iii) One-way and Two-way Analysis of Variance
   iv) Analysis of Covariance

3) Linear Panel Models
   i) Pooled Models
   ii) The Fixed Effects Estimator
   iii) The Random Effects Estimator
   iv) Mixed Models
   v) GMM Estimators for Panel Data
   vi) Application: Firms, Productivity and Technical Change (Industrial Organization)

4) The Evaluation Problem
   i) Randomized Experiments
   ii) Matching Models
iii) The Difference-in-difference Estimators
iv) Instrumental Variables
v) Regression Discontinuity Design
vi) Models with Control Functions
vii) Application: Evaluation of Active Labor Markets Programs (Labor economics)

5) Repeated Measures and Longitudinal Designs
   i) Experiments and Quasi-experiments
   ii) Longitudinal Designs and Repeated Measures
   iii) Between-subjects Hypothesis Testing
   iv) Application: Behaviorally Motivated Policies (Behavioral/Experimental Economics)

6) Multinomial Models
   i) A Review of Logit and Probit Models
   ii) The Multinomial Logit Model
   iii) The Conditional Logit Model
   iv) The Nested Logit Model
   v) The Ordered Probit Model
   vi) Application: Location Choices and Agglomeration Economies (Economic Geography)

7) Models for Count Data
   i) Poisson Regression Model
   ii) Negative Binomial Regression Model
   iii) Hurdle Models
   iv) Application: Technology Diffusion with Patent Data (Economics of Innovation)

8) Survival/Duration Models
   i) On Censoring and Truncation
   ii) The Kaplan-Meier Curve
   iii) The Cox Regression Model
   iv) The Weibull Model
   v) Application: Market Access for Pharmaceutical Products (Health Economics)

9) Special seminar: Econometrics and Machine learning

Teaching Method:
Hands-on-tool approach combining theory and practice.

Bibliography:
Cameron and Trivedi (2005), Microeconometrics: Methods and Applications, Cambridge University Press.
Cameron and Trivedi (2010), Microeconometrics using Stata, Stata Press.
Angrist and Pischke (2009), Mostly Harmless Econometrics, Princeton University Press
**Final Exam:**
The assessment is based on the production of a short empirical project (50%), a written exam (30%) and the presentation/replication of a published scientific article (20%).

**Prerequisites:**
Foundations of Probability and Statistics; Econometrics I.
Economic Growth  
(Sant'Anna School for Advanced Studies - Pisa)  
Details available [here](#).

Economics of Innovation  
(Sant'Anna School for Advanced Studies - Pisa)  
Details available [here](#).

Evolutionary Foundations of Industrial Dynamics  
(Sant'Anna School for Advanced Studies - Pisa)  
Details available [here](#).
Evolutionary Game Theory
Ennio Bilancini
20 Hours

Learning Outcomes:
To provide students with a state of the art overview of evolutionary game theory which can be useful to the potential researcher in the area as well as the interested scholar who works in a related field (behavioral sciences, social sciences, complexity studies).

Abstract:
Evolutionary methods allow to study how behaviors and traits evolve in a population of interacting agents. The object of evolution can be a biological or cultural trait or a profile of strategies in a game. The process by which it changes can depend on fitness, imitation or optimization, possibly as the outcome of a deliberative process.

Lecture Contents:
1. Overview of Evolutionary Game Theory
   Basic concepts, techniques and findings, from ESS strategies to evolutionary stability.
2. Deterministic evolutionary dynamics
   Models of deterministic evolution, mostly based on replicator dynamics and imitation.
3. Stochastic evolutionary models
   Models of stochastic evolution, mostly based on markov chains. Equilibrium selection based on stochastic stability techniques.

Teaching Method:
Frontal lectures

Bibliography:

Final Exam:
A 10-page essay applying evolutionary game theory to a phenomenon decided by the student

Prerequisites:
The course is self-contained, but basic knowledge of game theory and markov chains is welcome.
Financial Economics
(Sant'Anna School for Advanced Studies - Pisa)
Details available here.
Firms, Business Analytics and Managerial Behavior  
Nicola Lattanzi  
20 Hours

Learning Outcomes:  
Students will learn how to observe and evaluate business behavior, as well as how to locate sources of potential competitive advantage. They will also learn the base to identify organizational barriers and corporate behaviors that sustain or challenge manager decisions and execution of strategies.

Abstract:  
The course is based on key business concepts that will support students develop the expertise required to understand and evaluate business behaviors, firms’ strategies and financial results. The course is composed of three modules: "Firms, business analytics and managerial behavior", "Business Behavior and Behavioral Strategy", "Business model for emerging markets". The course will describe the decision-making in competitive markets as well as in emerging markets at the business unit level, in which many key strategic choices and actions are formulated and undertaken. The essential “tool-kit” that combines a broad understanding of strategies, businesses and market dynamics and the new challenges of businesses in today’s world.

Lecture Contents:  
Firms, business analytics and managerial behavior  
1. Firm as a system of choices and decisions in progress: theory  
2. The system of forces in a business organization: efficiency in production and effectiveness in results  
3. Business performance and ways to represent: quantitative and qualitative languages in accounting. The Financial conditions and the Profit and Loss prospect  
4. The fundamental role of Human Being. Human capital and intellectual capital: evolution and analysis  
5. Technological progress, occupations and skills in a business combination: the analysis  
6. The financial statement. How to read and comprehend performances and results in a business organization: methodology and tools  
7. The financial statement. How to read and comprehend performances and results in a business organization: methodology and tools  
8. Strategy, forecast simulation versus predictive simulation, Business analytics  
9. Entrepreneurship and management in a complex scenario  
10. Neuroscience, brain and business

Teaching Method:  
Lectures, discussions, business cases, presentations.

Bibliography:  
Suggested readings will be provided for each topic.
Final Exam:
Critical paper presentations in at least four groups.

Prerequisites:
Basic knowledge of business economics.
Foundations of Probability and Statistical Inference
Irene Crimaldi
30 Hours

Learning Outcomes:
By the end of this course, students will:
- have the ability to employ the fundamental tools of Probability Theory in order to solve different kinds of problems,
- have the fundamental concepts of Statistical Inference in order to perform various kinds of statistical analysis,
- appreciate the importance of mathematical formalization in solving probabilistic problems and in performing statistical analysis,
- be able to independently read mathematical and statistical literature of various types and be life-long learners who are able to independently expand their probabilistic and statistical expertise when needed.

Abstract:
This course covers the fundamental concepts of probability and statistical inference. Some proofs are sketched or omitted in order to have more time for examples, applications and exercises.

Lecture Contents:
This course deals with the following topics:
- probability space, random variable, expectation, variance, cumulative distribution function, discrete and absolutely continuous distributions,
- random vector, joint and marginal distributions, joint cumulative distribution function, covariance,
- conditional probability, independent events, independent random variables, conditional probability density function, order statistics,
- multivariate Gaussian distribution, copula functions,
- probability-generating function, Fourier transform/characteristic function,
- types of convergence and some related important results,
- Mathematical Statistics (point estimation, interval estimation, hypothesis testing, linear regression, introduction to Bayesian statistics).

Teaching Method:
Frontal teaching

Bibliography:
- Slides and other material provided by the lecturer

**Final Exam:**
Written test

**Prerequisites:**
No
Funding and Management of Research and Intellectual Property
Marco Paggi
10 Hours

Learning Outcomes:
How to write a research/mobility project proposal; fundamentals on the management of intellectual property rights.

Abstract:
The long seminar aims at providing an overview of funding opportunities for PhD students' mobility, post-docs, and researchers (Erasmus+ scheme; scholarships by the Alexander von Humboldt Foundation; initiatives by the Deutscher Akademischer Austausch Dienst; scholarships offered by the Royal Society in UK; bilateral Italy-France exchange programmes; Fulbright scholarships; Marie Curie actions; grants for researchers provided by the European Research Council). For each funding scheme, specific hints on how to write a proposal are given. In the second part of the long seminar, fundamentals on the management of intellectual property rights (copyright transfer agreements, open access, patents, etc.) are provided.

Lecture Contents:
- Overview of funding schemes to support research mobility;
- Fundamentals of Intellectual Property Rights (patents, copyrights, etc.)

Teaching Method:
Powerpoint slides

Bibliography:
Handouts are provided to the participants.

Final Exam:
This long seminar has no final exam.

Prerequisites:
None
Learning Outcomes:
The goal is to equip students with an in-depth understanding of the main concepts and tools of game theory in order to enable them to successfully pursue research related to strategic behavior.

Abstract:
The course begins by providing a detailed discussion of the state of the art approach to the modeling of strategic situations as games. Then, basic solution concepts and their main refinements will be reviewed. Finally, prominent applications concerning incomplete and asymmetric information will be presented.

Lecture Contents:
Game concepts covered:
Dominance and iterative dominance, rationalizability, Nash equilibrium, subgame perfect Nash equilibrium, trembling hand perfect Nash equilibrium, weak perfect Bayes-Nash equilibrium, sequential equilibrium, perfect Bayes-Nash equilibrium, out-of-equilibrium beliefs refinements.

The discussion of all theoretical concepts will be accompanied by representative applications from economics and the social and behavioral sciences.

Teaching Method:
Frontal lectures

Bibliography:

Final Exam:
1/3 assignments, 1/3 final written exam, 1/3 essay

Prerequisites:
The course is self-contained, but being familiar with basic concepts from calculus, linear algebra, and probability theory is quite helpful.
Global Law
Andrea Averardi
10 Hours

**Learning Outcomes:**
By the end of the course students will be able to identify the most relevant legal features of globalization.

**Abstract:**
The course illustrates how globalization affects the international legal context and how global regulatory regime emerge and develop. With the examples taken from several different sectors (such as world trade, Internet, sports, finance, environment, public health, cultural heritage) the course will focus on the regulatory, institutional and procedural dimensions of international organizations and on the relationships between these latter and domestic legal orders.

**Lecture Contents:**
Administrative Law; European Administrative Law, Global Administrative Law; European Law; International Law; Public Law; Comparative Law.

**Teaching Method:**

**Bibliography:**
Course readings and materials will be provided at the beginning of the course.

**Final Exam:**
Evaluations will be based on student’s participation during the classes.

**Prerequisites:**
Specializing course for: Economics, Networks and Business Analytics.
History of Economic Thought
(Sant’Anna School for Advanced Studies - Pisa)
Details available here.
Learning Outcomes:
Getting familiar with analyzing, controlling, estimating, and identifying dynamical systems, with emphasis on linear dynamical systems in state-space form.

Abstract:
The course provides an introduction to dynamical systems, with emphasis on linear systems in state-space form. After introducing the basic concepts of stability, controllability and observability, the course covers the main techniques for the synthesis of stabilizing controllers (state-feedback controllers and linear quadratic regulators) and of state estimators (Luenberger observer and Kalman filter). The course also briefly covers data-driven approaches of parametric identification to obtain models of dynamical systems from a set of data.

Lecture Contents:

Teaching Method:
Lecture slides and blackboard

Bibliography:
Lecture slides available on-line.

Final Exam:
Typically a small research project, or discussion about a paper on a subject related to the course, or oral exam.

Prerequisites:
Linear algebra and matrix computation, calculus and mathematical analysis.
Industrial Dynamics
(Sant’Anna School for Advanced Studies - Pisa)
Details available here.
Learning Outcomes:
To master the concepts developed in the course material in such a way that independent research can be carried out. Demonstrate knowledge and understanding that provide a basis for originality in developing ideas, often related to a research context. Students should possess the learning outcomes that enable them to continue studying in a way that will be largely self-directed or autonomous.

Abstract:
This course will survey recent developments in theory and empirics of firm dynamics and its importance for aggregate outcomes such as innovation, growth and international trade. In particular, this class will center around the following questions: a) what are the key empirical regularities on firm dynamics and what are the principal measurement issues? b) what drives firms’ size and growth dynamics? c) what determines the dynamics of entrepreneurial growth and innovation by firms? d) how do different sources of firm-level heterogeneity influence aggregate outcomes? e) what drives the rise and fall of inter-firm collaboration and trade networks? Students are expected to be familiar with microeconomics and econometrics from the first-year sequence.

Lecture Contents:
Class 1: Gibrat Legacy
Class 2: Size distribution of business firms, theory
Class 3: Size distribution of business firms, empirics
Class 4: Growth-of-firm, theory
Class 5: Growth-of-firm, empirics 1 (econometrics)
Class 6: Size-Growth Relationship, theory
Class 7: Market Structure: The Bounds Approach
Class 8: Industry Dynamics
Class 9: Machine Learning Firm Dynamics
Class 10: Microfoundations of Aggregate Fluctuations

Teaching Method:
Lecture-cum-Demonstration

Bibliography:
Main reference:
Other references:
Final Exam:
- Final presentation of student research proposal: 70%
- Class participation and constructive discussion of other students’ research ideas: 30%

Prerequisites:
Microeconomics, Econometrics I & II
Industrial Organization and Market Failure  
(Sant’Anna School for Advanced Studies - Pisa)  
Details available [here](#).

Introduction to Agent-Based Economics  
(Sant’Anna School for Advanced Studies - Pisa)  
Details available [here](#).

Introduction to Economic History  
(Sant’Anna School for Advanced Studies - Pisa)  
Details available [here](#).

Introduction to Macroeconomics

Syllabus is included in “Macroeconomics” (Sant'Anna School for Advanced Studies - Pisa)
Introduction to Network Theory
Guido Caldarelli
10 Hours

Learning Outcomes:
Being able to understand the basic concepts and theoretical frameworks in complex network theory

Abstract:
The course will provide an introduction to the mathematical basis of Complex Networks and their use to describe, analyze and model a variety of physical and economic situations.

Lecture Contents:
LECTURE 01 Graph Theory Introduction
LECTURE 02 Properties of Complex Networks I
LECTURE 03 Properties of Complex Networks II
LECTURE 04 Communities
LECTURE 05 Different kind of Graphs
LECTURE 06 Ranking
LECTURE 07 Static Models of Graphs
LECTURE 08 Dynamical Models of Graphs
LECTURE 09 Fitness Models
LECTURE 10 Financial Networks

Teaching Method:
Slides

Bibliography:
• G. Caldarelli Scale-Free Networks OUP (2007) (made available to students).
• Easley, Kleinberg “Networks Crowds and Markets” CUP (2010)
• http://barabasilab.neu.edu/networksciencebook/

Final Exam:
essay by students

Prerequisites:
basic of mathematics
Learning Outcomes:
At the end of the course, the student will have a basic knowledge of a quite-large set of commonly-used machine-learning techniques.

Abstract:
The course provides an introduction to basic concepts in machine learning. Topics include: learning theory (bias/variance tradeoff, Vapnik-Chervonenkis dimension and Rademacher complexity, cross-validation); supervised learning (linear regression, logistic regression, support vector machines); unsupervised learning (clustering, principal and independent component analysis); semisupervised learning (Laplacian support vector machines); online learning (perceptron algorithm); hidden Markov models.

Lecture Contents:
Lecture 1: Introduction to supervised learning and regression.
Lecture 2: Classification problems.
Lecture 3: Online learning: the perceptron learning algorithm and the LQG online learning framework.
Lecture 4: Unsupervised learning.
Lecture 5: Introduction to statistical learning theory.
Lecture 6: Structural risk minimization and support vector machines.
Lecture 7: A joint application of econometrics and machine learning: trade-off between sample size and precision of supervision.
Lecture 10: Connection between supervised learning and reinforcement learning.

Moreover, the teacher will illustrate some of the methods above, based on MATLAB implementations.

Teaching Method:
The teacher will project slides on the screen (a copy of the slides and of the MATLAB code will be provided to the students).

Bibliography:
The following books are related to the course. They can be useful as a supplementary material.


The following are slides/lectures notes from related courses.


The following reference reports commented MATLAB code for some of the machine-learning techniques examined in the course.

P. Kim, ”MATLAB Deep Learning With Machine Learning, Neural Networks and Artificial Intelligence,” Apress, 2017

**Final Exam:**
The student will prepare slides for a short seminar (20-30 minutes) on a topic related to machine learning. The topic of the seminar will be either proposed by the teacher or chosen by the student. The date of the seminar will be agreed between the student and the teacher. The seminar will take place either in the teacher’s office or in the classroom (in case several students will decide to have their seminars in the same day).

**Prerequisites:**
Calculus.
Macroeconomics
(Sant'Anna School for Advanced Studies - Pisa)
Details available here.
Markov Processes  
(Sant’Anna School for Advanced Studies - Pisa)  
Irene Crimaldi  
12 Hours

Learning Outcomes:  
By the end of this course, students will:  
- be familiar with Markov processes in discrete and continuous time,  
- be able to employ the fundamental tools of Markov Processes Theory in order to solve different kinds of problems,  
- appreciate the importance of mathematical formalization in solving probabilistic problems,  
- be able to independently read mathematical and statistical literature of various types.

Abstract:  
This course covers the fundamental results regarding Markov processes. Some proofs are sketched or omitted in order to have more time for examples, applications and exercises.

Lecture Contents:  
This course deals with the following topics:  
- Markov chains (definitions and basic properties, classification of states, invariant measure, stationary distribution, ergodic limit theorem, random walk and Gambler's ruin problem);  
- Poisson process (definition, properties and applications);  
- Markov processes with continuous time (definitions, Markov property, generator, forward Kolmogorov equations, stationary probability distribution);  
- Birth-Death processes and queues.

Teaching Method:  
Frontal teaching

Bibliography:  
- Slides and other material provided by the lecturer  

Final Exam:  
Without exam

Prerequisites:  
Basics of probability theory
Learning Outcomes:
The course is aimed to review basic concepts of matrix algebra at an intermediate/advanced level.

Abstract:
The course is aimed to review the following basic concepts of linear algebra:
- systems of linear equations: solution by Gaussian elimination, PA=LU factorization, Gauss-Jordan method;
- vector spaces and subspaces, the four fundamental subspaces, and the fundamental theorem of linear algebra;
- determinants and eigenvalues, symmetric matrices, spectral theorem, quadratic forms;
- Cayley-Hamilton theorem, functions of matrices, and application of linear algebra to dynamical linear systems;
- iterative methods for systems of linear equations;
- ordinary least squares problem, normal equations, A=QR factorization, condition number, Tikhonov regularization;
- singular-value decomposition, Moore-Penrose pseudoinverse;
The course also shows how to apply the methods above using MATLAB. Finally, an economic application of matrix algebra (the Leontief input-output model) is also detailed.

Lecture Contents:
- Systems of linear equations;
- Properties of systems of linear equations;
- Determinant and eigenvalues;
- Applications of eigenvalues;
- QR factorization, ordinary least squares problem, and variations;
- An economic application of linear algebra: the Leontief input-output model.

Teaching Method:
The teacher will project slides on the screen (a copy of the slides and of the MATLAB code will be provided to the students). He will also solve some exercises on the blackboard.

Bibliography:
MATLAB teaching codes based on Prof. Strang's books:
http://web.mit.edu/18.06/www/Course-Info/Tcodes.html
Students having already a good background in matrix algebra are encouraged to read the following more advanced topics from the second book by Prof. Strang:
- application of linear algebra to graphs (Section 2.5),
- application of Gram-Schmidt orthogonalization process to function spaces (Section 3.4),
- Fast Fourier transform (Section 3.5),
- complex matrices (Section 5.5),
- minimum principles (Section 6.4),
- finite element method (Section 6.5),
- linear programming, the simplex method, and duality (Sections 8-1-8.4),
- Jordan’s canonical decomposition (Appendix B).

**Final Exam:**
Final written examination (optional, 2 hours)

**Prerequisites:**
None, but since this is a 10-hours review course, it is highly advisable to have already attended a course about matrix algebra in the past.
Microeconometrics
(Sant'Anna School for Advanced Studies - Pisa)
Details available here.
Learning Outcomes:
Acquire a solid understanding of classical microeconomic theory; learn how to read and write mathematical proofs; learn to apply the concepts discussed in class to solve specific exercises

Abstract:
The course aims at introducing students to graduate-level microeconomic theory. The course will give emphasis to problem solving. For this reason problem sets will be assigned during the course at dates to be communicated in class. Students will then rotate on the board in the following lecture to discuss the problems.

Lecture Contents:
Consumer Theory; Producer Theory; Choice under uncertainty; Partial equilibrium and market structure; General Equilibrium; Externalities and Public Goods; Elements of Social Choice Theory (time permitting)

Teaching Method:
Lectures

Bibliography:
There is no required textbook for the course. However, the material presented in class will be taken from Mas-Colell, Whinston, and Green "Microeconomic Theory", which you are encouraged to consult

Final Exam:
Yes

Prerequisites:
Knowledge of intermediate-level microeconomics is helpful but not necessary.
Learning Outcomes:
Acquire a solid understanding of classical microeconomic theory; learn how to read and write mathematical proofs; learn to apply the concepts discussed in class to solve specific exercises.

Abstract:
The course aims at introducing students to graduate-level microeconomic theory. The course will give emphasis to problem solving. For this reason problem sets will be assigned during the course at dates to be communicated in class. Students will then rotate on the board in the following lecture to discuss the problems.

Lecture Contents:
Consumer Theory; Producer Theory; Choice under uncertainty; Partial equilibrium and market structure; General Equilibrium; Externalities and Public Goods; Elements of Social Choice Theory (time permitting)

Teaching Method:
Lectures

Bibliography:

Final Exam:
yes

Prerequisites:
Knowledge of intermediate-level microeconomics is helpful but not necessary. Students should have a working knowledge of calculus and linear algebra on the undergraduate level.
Models of Causality and Explanation in Economics
(Sant'Anna School for Advanced Studies - Pisa)
Details available [here](#).
Neurobiology of Emotion and Behavior
Pietro Pietrini
12 Hours

Learning Outcomes:
By attending this Course, students will learn the fundamentals of the neurobiological correlates of emotion and behavior and their evolutionary meaning under physiological conditions. Neurobiological correlates and effects of altered mental conditions on emotion and behavior also will be discussed.

Abstract:
The body of knowledge gained in the field of neuroscience in the last quarter of century have changed the way we conceptualize mind, behavior and even human nature. Since the 19th century it has been known that lesions to the cerebral cortex may lead to impairments in specific cognitive functions and in the ability to modulate behavior. The recent development of modern methodologies for investigating brain functions, including positron emission tomography and functional magnetic resonance imaging has made it possible to investigate the neural circuits implicated not only in cognitive processes such as perception, attention, memory and language, but also in more elusive mental functions, including emotion and behavior. In addition, molecular biology and genetics have led to the decoding of the human genome and are now investigating the role that the genetic endowment plays in shaping not only physical, but also personality features, behavior and vulnerability to mental disorders.

Lecture Contents:
* Brain structures involved in emotion and behavior in humans, non humans primates and other vertebrates. Why it is important to study the neurobiological correlates of emotion and behavior in the human brain
* Brain functional and structural correlates of emotion and behavior in humans. How structural and functional brain imaging methodologies can be applied to the in vivo study of human emotion and behavior
* Brain response to fearful stimuli. The role of amygdala. Emotions as a way to enhance signal-to-noise ratio in information processing. Evolutionary meaning of emotional processing
* Mood influence on emotional brain response. Effects of priming on amygdala response to neutral and sad stimuli. Implications for the understanding of the effects of environmental factors on mood balance
* Effects of negative life events on brain structures. Implications for the neurobiology of depression. Effects of meditation on brain structure and function
* Cognitive and emotional determinants in behavioral modulation. From instinct to decision making. The neural correlates of aggressive control in the healthy human brain. Altered structural and functional cortical and subcortical factors in behavioral dysfunctions: implications for mental insanity in the forensic context
* The human genome. Genetic alleles involved in emotional processing and behavior. Genetic vulnerability to mood disorders
* Moral behavior. Cognitive and emotional aspects. The genetic factors that may influence human moral decisions
* Genes and environmental factors in shaping individual social behavior and vulnerability to psychological distress and depression

* Implications of recent neuroscience acquisitions about human emotion and behavior for the social sciences and the law

**Teaching Method:**
The course includes theoretical and methodological face-to-face lessons, with the help of slides and experimental research publications. E-learning platform are used to share learning materials (slides, data, publications, etc.)

**Bibliography:**
Lesson slides; selected papers of studies and case reports discussed in class

**Final Exam:**
Knowledge will be verified throughout the course by student's engagement into discussion in class; a written examination with open questions and multiple choice questions will be administered at the end of the course

**Prerequisites:**
Basic knowledge of brain imaging methodologies. It is strongly suggested, though not mandatory, that students have followed the following courses prior to enroll in this one: Introduction to Cognitive and Social Psychology; Basic Principles and Applications of Brain Imaging Methodologies to Neuroscience.
Non Parametric Statistics
(Sant'Anna School for Advanced Studies - Pisa)
Details available here.
Numerical Methods for the Solution of Partial Differential Equations
Marco Paggi
20 Hours

Learning Outcomes:
Ability to solve numerically a problem related to a physical system and predict its response. The physical system can be embedded within an optimization problem, for instance, or it can be part of a complex system (biological, mechanical, thermo-mechanical, chemical, or even financial) you are interested in predicting its behaviour and evolution over time.

Abstract:
The course introduces numerical methods for the approximate solution of initial and boundary value problems governed by linear and nonlinear partial differential equations (PDEs) used to describe physical systems. The fundamentals of the finite difference method and the finite element method are introduced step-by-step in reference to exemplary model problems taken from heat conduction, linear elasticity, and pricing of stock options in finance. Notions on numerical differentiation, numerical integration, interpolation, and time integration schemes are provided. Special attention is given to the implementation of the numerical schemes in finite element analysis programmes for fast intensive computations.

Lecture Contents:
- Numerical differentiation schemes
- Numerical interpolation schemes
- Numerical integration schemes
- Time integration algorithms
- Newton-Raphson incremental-iterative schemes for nonlinear problems
- Finite difference method
- Finite element method

Teaching Method:
Blackboard. Handouts are also provided.

Bibliography:

Final Exam:
An application of the taught methodologies to one case study of relevance for the PhD student's research is recommended. Alternatively, a topic to investigate can be suggested by the lecturer.

Prerequisites: The course is self-contained. Fundamentals of algebra are required.
Learning Outcomes:
Learn how to model optimal decision problems as optimization problems and how to solve them using numerical optimization packages. By learning the basic theory behind the most used numerical optimization methods (optimality conditions, sensitivity, duality) and understanding how the algorithms work, the student will be able to formulate real-life optimization problems and to choose the most appropriate algorithms to solve them, or to develop new optimization algorithms or adapt existing ones to solve them.

Abstract:
Optimization plays a key role in solving a large variety of decision problems that arise in engineering (design, process operations, embedded systems), data science, machine learning, business analytics, finance, economics, and many others. This course focuses on formulating optimization models and on the most popular numerical methods to solve them, including active-set methods for linear and quadratic programming, proximal methods and ADMM, stochastic gradient, interior-point methods, line-search methods for unconstrained nonlinear programming.

Lecture Contents:

Teaching Method:
Lecture slides and blackboard.

Bibliography:
Lecture slides available on http://cse.lab.imtlucca.it/~bemporad/optimization_course.html
Final Exam:
Typically a small research project, or discussion about a paper on a subject related to the course, or oral exam.

Prerequisites:
Linear algebra and matrix computation, calculus and mathematical analysis.
Learning Outcomes:
At the end of the course, the student will be able to formulate optimal control problems and will know a wide range of techniques that can be applied for solving such problems.

Abstract:
The course provides an overview of optimal control theory for the deterministic and stochastic cases. Both discrete-time and continuous-time problems are considered.

Lecture Contents:
- An overview of optimal control problems.
- An economic example of an optimal control problem: the cake-eating problem.
- Dynamic programming and Bellman’s equations for the deterministic discrete-time case.
- Reachability/controllability and observability/reconstructability for time-invariant linear dynamical systems.
- The Hamilton-Jacobi-Bellman equation for continuous-time deterministic optimal control problems.
- Pontryagin’s principle for continuous-time deterministic optimal control problems.
- LQ optimal control in discrete time for deterministic problems.
- Application of dynamic programming to stochastic and infinite-horizon optimal control problems in discrete time.
- LQ optimal control in discrete time for stochastic problems and Kalman filter.
- Introduction to approximate dynamic programming and reinforcement learning.
- An economic application of optimal control: a dynamic limit pricing model of the firm.

Teaching Method:
The teacher will project slides on the screen (a copy of the slides will be provided to the students).

Bibliography:
The following books are related to the course. They can be useful as a supplementary material.


The following are slides/lectures notes from related courses.


**Final Exam:**
The student will prepare slides for a short seminar (20-30 minutes) on a topic related to optimal control. The topic of the seminar will be either proposed by the teacher or chosen by the student. The date of the seminar will be agreed between the student and the teacher. The seminar will take place either in the teacher’s office or in the classroom (in case several students will decide to have their seminars in the same day).
Prerequisites:
Matrix algebra, calculus.
Learning Outcomes:
On completing the course, the students will have an enhanced capacity of understanding and evaluating past and current debates about the reliability, the rationality and the limits of science. They can assess the scope and limits of scientific knowledge and appreciate the differences and relations between science and other scientific endeavours. They understand why and to what extent science is rational and often successful, and what is its role in guiding decision-making in modern societies.

Abstract:
The course provides an introduction to the basic concepts and problems in the philosophical analysis of scientific reasoning and inquiry. We will focus on some central patterns of reasoning and argumentation in science and critically discuss their features and limitations. Topics covered include the nature of theory and evidence, the logic of theory testing, and the debate about the aims of science and the trustworthiness of scientific results. We shall discuss classical examples and case studies from the history and practice of science to illustrate the relevant problems and theoretical positions. Students will freely engage in brainstorming on these topics and are welcome to propose examples, problems, and methods from their own disciplines.

Lecture Contents:
The topic of each lesson will be decided at the beginning of the course on the basis of student’s feedback; the following is a tentative list subject to change.

Lecture 1. Presentation of the course. Discussion and choice of specific topics. What is science?
Lecture 2. How many sciences? The method(s) of science. Exact and inexact sciences.
Lecture 3 Theories, models, data. Experiments and observations.
Lecture 4. Inferences in science. Falsification, confirmation, disconfirmation.
Lecture 6. History of science and scientific progress. The aim(s) of science.
Lecture 7. Science, truth, and reality.
Lecture 8. Recap, verification and general discussion.

Teaching Method:
Mixture of lectures and discussion seminar.

Bibliography:
We won't have a textbook or a proper reading list. Relevant readings will be shared on Google Drive. The following are suggestions for background readings and possible topics of discussion.


**Final Exam:**
Active contribution from the participants is a prerequisite for passing the course.

**Prerequisites:**
None.
Political Economy
Alessandro Belmonte
20 Hours

Learning Outcomes:
Students will learn the principal methods and some major empirical applications of modern political economy, including how to apply games to political economic situations and how to apply empirical methods to test political economy theories.

Abstract:
The course is a relatively advanced (i.e. at the beginning graduate level) but essentially self-contained introduction to the methods and some major applications of modern political economy.

Lecture Contents:
Topics:
- Institutions and “exogenous” differences in institutions
- At the origin of institutions: From Social Choice to Political Economics
- Median voter models and redistributive politics
- Probabilistic voting models
- Agency models of politics: Electoral accountability and career concerns
- Endogenous Institutions: Institutional transitions and conflicts.

Teaching Method:
Direct instruction complemented by active participation of students. Students will also be asked to present and discuss some relevant empirical works.

Bibliography:
Textbooks:
2) Daron Acemoglu, Political Economy Lecture Notes.

Additional Readings:
2) James Feyrer and Bruce Sacerdote, Colonialism and Modern Income: Islands as Natural Experiments, RESTAT 2009
3) Toke S. Aidt, Raphaël Franck, Democratization Under the Threat of Revolution: Evidence From the Great Reform Act of 1832, ECMA 2015
5) Sascha O. Becker and Luigi Pascali, Religion, Division of Labor and Conflict: Anti-Semitism in German Regions over 600 Years, AER 2019
6) Alesina Alberto and Fuchs-Schündeln Nicola, Goodbye Lenin (or Not?): The Effect of Communism on People's Preferences, AER 2007
7) Fernanda Brollo, Tommaso Nannicini, Roberto Perotti, and Guido Tabellini, The Political Resource Curse, AER 2013

**Final Exam:**
The exam develops in two parts: 1) students' presentation of an empirical article and 2) a summary of an article

**Prerequisites:**
The course assumes a good knowledge of macro and microeconomics (especially some growth theory, elementary taxation theory and game theory, including games with asymmetric/incomplete information and the theory of repeated games), of mathematical and statistical methods (especially static and dynamic optimization), and some introductory knowledge of econometric tools (especially familiarity with the issue of causality in econometrics and IV estimation), at the level of the relevant courses offered at IMT.
Learning Outcomes:
To master the concepts developed in the course material in such a way that independent research can be carried out. Learn the socio-economic approach to the analysis of networks.

Abstract:
The main topic of the course is the analysis of socio-economic networks. The course will consist of three parts: (1) basic notions of graph theory and social network analysis; (2) micro level networks of individuals and firms; (3) meso and macro-level networks of sectors and countries. The first part will focus on some basic notions of social network analysis. Individual and inter-organizational networks will be analyzed. In the second part, with a special focus on the division of (innovative) labor within and across firm boundaries. The third part on the empirics of meso and macro networks in economics will have a strong focus on international trade, human mobility and finance. All parts will give you a brief overview on the literature, which predominantly adopted an econometric approach to the analysis of networks.

Lecture Contents:
Section I: Graph theory and social network analysis
- Class 1: Graph Theory and Social networks: basic concepts; embeddedness, reflection problem; diffusion & homophily
- Class 2: Small world, cascading behavior and information cascades
- Class 3: Power laws, preferential attachment
- Class 4: Network effects, epidemics

Section II: Socio-economic networks: Individuals and Organizations
- Class 5: Interorganizational networks: Firms’ collaborative agreements; networks of innovators
- Class 6: Influence and peer effects in social networks

Section III: Empirics of Meso and Macro-Economic Networks
- Class 7: Networks of trade and production
- Class 8: Migration and human mobility
- Class 9: Input-Output networks
- Class 10: Financial networks and systemic risk

Teaching Method:
Lecture-cum-Demonstration

Bibliography:
Main text:

Other readings:
Other reading materials:

**Final Exam:**
- Referee Reports: 40% Select a recent working paper or a classical paper not covered in the class and write a referee report on it. The paper selected has to be approved by the instructors.
- Term Paper: 60% A research proposal, with clearly stated questions, adequate literature survey, and proposed approaches.

**Prerequisites:**
Introduction to Network Theory
Static and Dynamic Optimization
(Sant’Anna School for Advanced Studies - Pisa)
Details available here.

Statistical Methods for Large Complex Data
(Sant’Anna School for Advanced Studies - Pisa)
Details available here.
Learning Outcomes:
By the end of this course, students will:
- be familiar with some important stochastic processes,
- be familiar with Ito stochastic calculus,
- be able to identify appropriate stochastic process model(s) for a given research problem,
- appreciate the importance of mathematical formalization in solving probabilistic and statistical problems,
- be able to independently read mathematical and statistical literature of various types and be life-long learners who are able to independently expand their probabilistic and statistical expertise when needed.

Abstract:
This course aims at introducing some important stochastic processes and Ito stochastic calculus. Some proofs are sketched or omitted in order to have more time for examples, applications and exercises.

Lecture Contents:
This course deals with the following topics:
- Markov chains (definitions and basic properties, classification of states, invariant measure, stationary distribution, ergodic limit theorem, cyclic classes, passage problems);
- conditional expectation and conditional variance;
- martingales (definitions and basic properties, Burkholder transform, stopping theorem and some applications, predictable compensator and Doob decomposition, some convergence results, game theory, random walks, urn models);
- Wiener process (definitions, some properties, Donsker theorem, Kolmogorov-Smirnov test)
- Ito calculus (Ito stochastic integral, Ito processes and stochastic differential, Ito formula, stochastic differential equations, Ornstein-Uhlenbeck process, Geometric Brownian motion, Feynman-Kac Representation formula).

Teaching Method:
Frontal teaching

Bibliography:
- Slides and other material provided by the lecturer
- D. Williams, Probability with martingales, Cambridge Univ. Press (1991)
Final Exam:
Seminar with a short written report on the topic of the seminar

Prerequisites:
Basics of probability theory and statistical inference
Strategies and Business Behavior
Nicola Lattanzi
20 Hours

Learning Outcomes:
Students will learn how to observe and evaluate business behavior, as well as how to locate sources of potential competitive advantage. They will also learn the base to identify organizational barriers and corporate behaviors that sustain or challenge manager decisions and execution of strategies.

Abstract:
The course is based on key business concepts that will support students develop the expertise required to understand and evaluate business behaviors, firms’ strategies and financial results. The course is composed of three modules: "Firms, business analytics and managerial behavior", "Business Behavior and Behavioral Strategy", "Business model for emerging markets". The course will describe the decision-making in competitive markets as well as in emerging markets at the business unit level, in which many key strategic choices and actions are formulated and undertaken. The essential “tool-kit” that combines a broad understanding of strategies, businesses and market dynamics and the new challenges of businesses in today’s world.

Lecture Contents:
Strategies and Business Behavior
1 Market and strategy: volatility and development
2 What strategic management is
3 A focus on specific firms and competitive advantage
4 The extraordinary life of patterns and trends: how to learn for a business organization? (1)
5 The extraordinary life of patterns and trends: how to learn for a business organization? (2)
6 Cyber-time and cyber-space for humans and virtual humans: business dynamics and organizations
7 Business behavior and patterns of innovation
8 Behavioral strategy: rational approach, heuristic system and cognitive biases
9 Business behavior and behavioral strategy: fundamentals and case study. A short view on a critical business behavior
10 Data Science for business: network theory for strategy and management

Teaching Method:
Lectures, discussions, business cases, presentations.

Bibliography:
Suggested readings will be provided for each topic.

Final Exam:
Critical paper presentations in at least four groups.
Prerequisites:
Basic knowledge of business economics.
Theories of the Firm
(at Sant'Anna School for Advanced Studies - Pisa)
Details available here.

Time Series
(Sant'Anna School for Advanced Studies - Pisa)
Details available here.

Topics in Macro
(Sant'Anna School for Advanced Studies - Pisa)
Details available here.