Learning and information in economic settings with and without beliefs

Course organizers/Lecturers: Peter Norman Sørensen and Karl Schlag

Course description

In the face of risk and uncertainty, how does new information affect economic decisions? The course examines this question both within the workhorse model of Bayesian belief updating and in more recent belief-free models. Participants in the course will obtain insights into questions, methods, and applications, preparing well for further research.

In the Bayesian model, we first review properties of updating beliefs in single-player learning environments. In applications to binary hypothesis testing, emphasis is placed on martingale properties of beliefs and likelihood ratios. We also discuss the comparative statics of actions with respect to beliefs and information, including the monotone likelihood ratio property. We turn to two more advanced topics. One is the comparison of information structures as first proposed by Blackwell, and later extended by Lehmann. The other is application to multi-player settings, emphasizing social learning and herding with learning cascades.

In the belief-free approach, we start from static choice problems. This part starts from alternative interpretations of belief elicitation outcomes. The part continues with a theory of beating the play, reacting to out-of-equilibrium play in a game without beliefs, including an application to robust bidding in auctions. In this context, minimax regret has interesting properties. The remaining part considers dynamic choice problems. Social learning can be effective through imitation, without any need for beliefs – reinforcement learning (well-known also from large language models) provides a flexible belief-free tool for learning and responding to new information. The non-guessing approach similarly allows for good outcomes in the true state without any need for beliefs.

Course Objectives

Upon completion of the course, the students will have

Knowledge of

- central concepts in Bayesian belief updating under risk and uncertainty
- main differences between Bayesian and belief-free approaches to learning and decision-making
- key applications such as hypothesis testing, information structures, social learning, herding, and reinforcement learning

Skills to

- explain how new information affects decisions in simple Bayesian models
- apply basic analytical tools such as likelihood ratios, martingale reasoning, and comparative statics with respect to beliefs and information
- compare Bayesian and belief-free approaches in selected economic settings, such as auctions or social learning problems

Competences

- assess which modelling approach is appropriate for a given economic decision problem under uncertainty
- critically discuss the strengths and limitations of belief-based and belief-free models in current research
- formulate a small research question related to learning, information, and economic decision-making

Course format

The two course organizers provide lectures on these topics. We assume that students have already learned game theory at a level that is typical for programs in Economics. Students are expected to prepare before the lectures, both to obtain a basic understanding of the required reading material, and to think of questions.

Both days will have course lectures in the morning and afternoon (9:00-12:00, 14:00-17:00 on Day 1, 8:45-10:15, 13:00-16:30 on Day 2). Moreover, on the second day, a session includes presentations of current research by both lecturers (10:30-12:00).

Towards the end of the course, we briefly list some topics for further work. In order to obtain credit for the course, each student must subsequently write a short paper on one such topic, or a similar topic approved by the organizers. More information is provided during the course.

Readings

Susan Athey (2001): "Single crossing properties and the existence of pure strategy equilibria in games of incomplete information." Econometrica 69 (4), 861-889.

Susan Athey (2002): "Monotone comparative statics under uncertainty." The Quarterly Journal of Economics 117 (1), 187-223.

Dirk Bergemann and Stephen Morris (2016): “Bayes correlated equilibrium and the comparison of information structures in games” Theoretical Economics 11(2), 487-522.

Henrique de Oliveira. "Blackwell's informativeness theorem using diagrams." Games and Economic Behavior 109 (2018): 126-131.

Alfredo Di Tillio, Marco Ottaviani and Peter Norman Sørensen (2021): "Strategic sample selection." Econometrica 89 (2), 911-953.

Bernhard Kasberger and Karl H Schlag (2024): ”Robust bidding in first-price auctions: How to bid without knowing what others are doing.” Management Science 70 (7), 4219-4235.

Erich L. Lehmann (1988): "Comparing Location Experiments." The Annals of Statistics, 521-533.

Pietro Ortoleva (2024): "Alternatives to bayesian updating." Annual Review of Economics 16 (1), 545-570.

Marco Ottaviani and Peter Norman Sørensen (2015): "Price reaction to information with heterogeneous beliefs and wealth effects: Underreaction, momentum, and reversal." American Economic Review 105 (1), 1-34.

John K-H. Quah and Bruno Strulovici (2009): "Comparative statics, informativeness, and the interval dominance order." Econometrica 77 (6): 1949-1992.

Ludovic Renou and Karl Schlag (2010): “Minimax regret and strategic uncertainty.” Journal of Economic Theory 145 (1), 264-286.

Karl Schlag (1998): “Why imitate, and if so, how?: A boundedly rational approach to multi-armed bandits.” Journal of economic theory 78 (1), 130-156.

Karl H. Schlag, James Tremewan and Joël J. Van der Weele (2015): “A penny for your thoughts: A survey of methods for eliciting beliefs.” Experimental Economics 18(3), 457-490.

Karl H. Schlag (2025): "Learning From The Data: A Theory Without Guessing." Available at SSRN 5182183 (2025).

Lones Smith and Peter Sørensen (2000): "Pathological outcomes of observational learning." Econometrica 68 (2), 371-398.